SEVEN YEAR TOPICAL INDEX

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WITH

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(4) Approximate practical diagram; (5) experimental determination of inductive resistance of a transformer; (6) Kapp's diagram for pre-determination of drop and regulation; (7) diagram of auto-transformer. Explanation; diagrams; examples. D-8, W-2200. Vol. I, p. 410, Aug., '04.

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The aim ot the Journal is to be direct, definite and practical, and to be recognized by progressive electrical men as one of the indispensable aids to effective engineering work.

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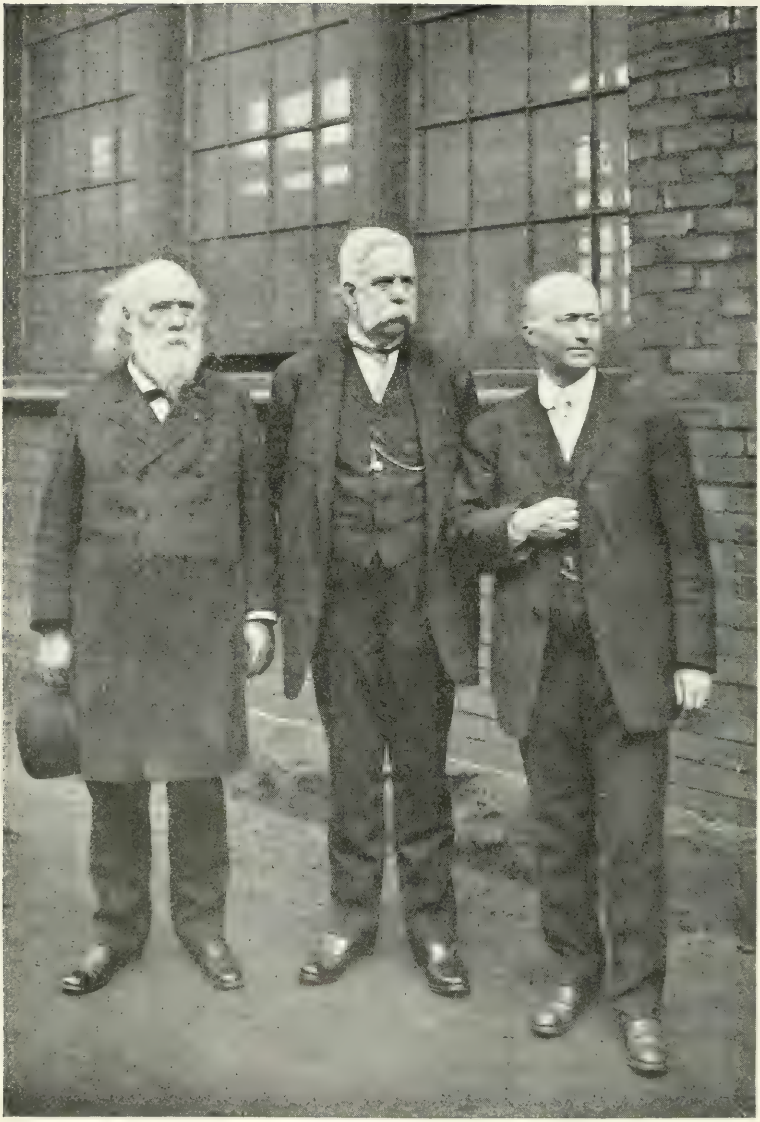

GEORGE W. MELVILLE JOHN H. MACALPINE
GEORGE WESTINGHOUSE

THE
ELECTRIC JOURNAL

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THE NEW REDUCTION GEAR

BIOGRAPHICAL sketches of the three men who are responsible for the development of the new Melville and Macalpine Reduction Gear are given below:

GEORGE W. MELVILLE

Admiral Melville was born in New York City and received his education as a pupil in the public schools of that city and as an apprentice in a machine shop. He was nearly 21 years of age when he entered the United States Navy at the beginning of the Civil War. He proved an efficient engineer and established a reputation for fearlessness and courage. After the war he remained in the Engineer Corps and rose through various grades to that of Chief of the Bureau of Steam Engineering. He was a member of the Jeannette Polar Expedition in 1878. The vessel was lost and the party, after a long march over the ice, separated into three boat crews. His crew alone reached ultimate safety. His heroic search for his comrades among the snow and desolation of Northern Siberia made his name known the world over. The sufferings and hardship which he underwent were almost beyond the limit of human endurance. He finally made his way alone in intense cold, through a desolate country of half civilized people of foreign tongue for 2 000 miles. He had already been to the Arctic region in the Hall relief expedition in the steamer "Tigress," and later was in the Greely relief expedition in 1884.

After his return from these expeditions he had various special duties, relating to the development of new devices, on the trial of new ships and was for a time inspector at Cramps' ship-

yard. In 1887 he was made Engineer-in-Chief of the Navy. This was practically the time of the beginning of the modern Navy in which engineering construction is the pre-eminent feature. He was the responsible head of the engineering forces, and over a hundred vessels, aggregating a million and a quarter horse-power, owe their machinery designs to him.

He was wise enough to know, and strong enough to act. He was at once familiar with details and alert to the larger problems, recognizing existing limitations and proposing new methods. He introduced water tube boilers, but with discretion. The first success was not followed by promiscuous adoption, but the results of experience were awaited so that probable and costly errors were avoided. He was also responsible for the phenomenal success of the triple screw flyers, Columbia and Minneapolis, which for a number of years were the fastest large vessels in the world. During his entire term of sixteen years he contantly encouraged experimentation and everything looking to progress, and gave the benefit to the engineers of the country by full accounts in his annual reports.

He retired from the Navy soon after reaching the age limit of 62 in 1903. Since that time he has been a consulting engineer and naval architect, with Mr. John H. Macalpine as a partner. His whole experience in the Navy has been such as to give him a thorough knowledge of the ideal requirements and the practical limitations of the development of power on ship-board and he is, therefore, peculiarly fitted to point out the line of development and to take an active part in devising the means by which a new power may bring about a new era in navigation.

GEORGE WESTINGHOUSE

Mr. Westinghouse was born at Central Bridge, Schoharie County, New York, October 6th, 1846. His father was a manufacturer in Schenectady, and it was in his shop that he acquired much of his skill as a mechanic. His early education was limited to the common school and he became an inventor at the age of fifteen, conceiving something entirely new in the form of a rotary

engine, which he constructed with his own hands, even then accustomed to the use of tools.

In the Civil War he served both in the infantry and cavalry of the army, and for the last year of the war as an engineer officer in the navy, resigning when the fighting was over.

After a short stay at Union College, he began active business life in the exploitation of a railroad switch which he had invented. This brought him in touch with railroad problems and impressed him by the need of an effective power brake. The successful use of compressed air in the construction of the Mount Cenis Tunnel was made public about this time. His mind had already formulated the mechanism, and here was the power—compressed air. In 1868 he invented the airbrake, which has been pronounced the greatest advance in railroading since Stephenson's use of forced draft in the Rocket.

The history of the introduction and development of the airbrake is one which tells the story of a man rising from obscurity to world-wide eminence, through a rare combination of mechanical genius, indomitable will and personal power. It is also interlinked with the development of the modern railway and the operation of heavy trains at high speeds with safety. In addition, it is a typical illustration of the development of a modern industry, beginning with a small shop, and growing with the later inventions and improvements in its products into a factory which is one of the most remarkable examples of highly specialized and efficient manufacturing in the world.

Familiarity with railway needs and with compressed air led naturally to the development of the pneumatic switch and signal for railroad work. The use of electricity in connection with the pneumatic valves led to a study of this comparatively new agent, out of which grew the greatest of the many Westinghouse companies, namely, the Electric Company.

One of the qualities for which Mr. Westinghouse is noted is his remarkable foresight. It was he who saw the limitations of direct current in the field of transmission and who was the pioneer in the introduction of alternating-current twenty years ago. The later single-phase development is another example of his foresight as to the coming requirements in railway service and his confidence in alternating current.

Mr. Westinghouse has taken a foremost part in the development of the gas engine and the steam turbine. He has, appar-

ently, never ceased to be fascinated and impelled by the same ideas which led to his first invention, a form of rotary engine. He was quick to recognize the possibilities of the Parsons turbine and to give to it the impetus of his personal effort and that of his engineering and mechanical forces. He has long recognized the possibilities which will be opened when the economies of the steam turbine can be utilized where slow speed and large power is required in the propelling of vessels. The new reduction gear is, therefore, no happy accident, but it is the logical outcome of an active lifetime of study and endeavor.

The following incident is described in a newspaper article relative to Mr. Westinghouse, which appeared about a year and a half ago:—

"During the dark days of the October panic, when men looked at each other and wondered where it was all going to end unless some power arose to stem the rapidly rising tide of distrust, Mr. Westinghouse sat in his office in the Penn avenue building and quietly talked over the situation with some of his most trusted associates. As the details of the situation were gone over he listened. Then, as though financial affairs were farthest from his thoughts, he turned to one of his friends with the remark:

"'I have an idea in connection with our steam turbine that will create a sensation when we bring it out.'"

On the 23rd of October, 1907, which was the darkest day of the panic, and at the very hour while the lawyers were busy with legal papers, Mr. Westinghouse telephoned to the factory asking that the report of Messrs. Melville and Macalpine on the turbine situation in Europe and the new reduction gear be sent to him at once; and he occupied himself during the day in their study. This was not a case of indifference to the crisis, for his whole fortune was in the balance, nor was it despair, though the stoutest hearts were quaking. It was a continuation of one of his most characteristic traits—not to spend time over matters that have been settled or have passed out of his hands—but to apply his energy always to constructive work. It was one of the most wonderful exhibitions of will-power and concentration on record. Such a man succeeds because he compels success.

JOHN H. MACALPINE

Mr. Macalpine is a Scotchman by birth and an honor graduate of the University of Glasgow, where he was a pupil of Lord Kelvin. After graduation he spent a number of years with the firm of R. Napier & Sons, of Glasgow, where he became the assistant to Dr. Kirk, the managing director, who is possibly best known from his work in the introduction of the triple expansion engine.

In the early '90s Mr. Macalpine came to this country and became acquainted with Admiral Melville, through whose recommendation he was appointed works manager of the Detroit Dry Dock & Engine Company. When that concern closed down during the panic of 1893, Mr. Macalpine accepted a position in the Bureau of Steam Engineering under Admiral Melville, where he spent some five years, during which time he wrote a series of articles, which was afterwards printed in book form, on "Elastic Stresses in Machinery."

In 1898 he returned to Scotland, where, for several years, he managed a ship and engine building works, but again returned to this country. He did some especially creditable work in modifications of the machinery of certain high speed torpedo boats to overcome difficulties due to vibration, and in this connection it may be mentioned that he is recognized as one of the foremost authorities on the subject of vibration of machinery. He is the inventor of a form of engine which is claimed to be perfectly balanced and is certainly extremely ingenious, but the method of balancing called the "Yarrow-Schlick-Tweedie System," which does not change the general type of engine, has held the field, although the balance is not so perfect as in Mr. Macalpine's design.

Some six years ago, when Admiral Melville was retired and relinquished his office as Engineer-in-Chief of the Navy, he and Mr. Macalpine formed a partnership as Consulting Engineers and Naval Architects. During this association they brought out the reduction gear, which is known by their name and which, through the financial backing of Mr. Westinghouse, has been given a complete demonstration on the large scale, as described elsewhere in this issue.

EDITORIALS

The Journal for 1910

This, the first issue of the JOURNAL in its seventh year, has a larger number of pages than any preceding issue by nearly fifty percent. While this is a special number, it is expected that all the issues during the coming year will show a notable increase in size over those in the past. There have not been sufficient pages to accommodate the material which has come to the editor's desk; the Question Box in particular has been condensed, and it is expected that additional space in the future will be devoted to this department, which has been proving so useful.

In looking back over the announcements at the beginning of each preceding year, it is found that the objects and purposes of the JOURNAL which they contain might be appropriately restated now. Suffice it to say that the JOURNAL still stands for progress and for higher efficiency in electrical work and in electrical men. Its aim is to be especially helpful to those who are entering or are in the beginning of their electrical career. Its ideal is to take up the questions and the problems which are foremost in electrical work and to treat them in a broad-gauge way. It seeks to avoid the language of the mathematician and the specialist and to put the things which it says in such a way that they will be clear to those who should know and use them.

The general field of electrical engineering, and the field of the JOURNAL, is broadening. Power transmission, electric railways, illumination, industrial power, electric heating, electro-chemistry, domestic utilization of electric current, these have all changed greatly since the JOURNAL started. The practically new field of commercial electrical engineering, the study of the concrete and definite application of electric apparatus to the work it is to do, the broadening field of the electrical engineer—particularly in industrial and manufacturing work—the new attitude of the central station toward the general public, which is using electricity in so small a measure compared with what it should, are all elements which are becoming more and more important in the broader vision of the electrical profession. The JOURNAL will fall short of its aim if it does not become more and more efficient in assisting those who want to keep in the forefront in electrical matters.

There are many who are not professional electrical engineers, but are engineers in other lines of work, or who are related in one way or another to the use of electricity, who will find in the JOURNAL articles of information and suggestion which will be helpful to them.

In general, the JOURNAL aims, in one way or another, to be useful to all who have to do directly or indirectly with the modern applications of electricity.

Hydro-Electric Plants

A noteworthy discussion following a noteworthy paper took place in New York City on the evening of December 16th last, when Mr. H. L. Doherty presented his paper on "Hydro-Electric Plants" before the American Institute of Electrical Engineers. The predominant note of the discussion was the reiteration of the statement that water power plants are, as a rule, far from being so profitable a form of investment as has been popularly supposed, and that it requires careful engineering judgment to determine whether or not for a given condition a given water power can successfully compete with steam. The general trend of the whole discussion was very well illustrated by Mr. Calvert Townley's epigrammatic remark, "The more I investigate water power, the better I like steam."

Mr. Townley's discussion was typical of much that was said during the evening. He went on to show that for normal conditions existing in New England, such as he was familiar with, the cost of fuel, with a twenty percent load-factor, runs from $6.00 to $8.00 per year per kilowatt of steam plant installed. Since fuel is by far the largest item that is saved when substituting water power for steam, it follows that the additional investment which may be incurred for a water power development over and above the cost of a steam plant must not be much greater than an amount upon which the fixed charges will be $6.00 to $8.00 per year per kilowatt installed. Thus, with the conditions named above, and allowing ten percent for fixed charges, one cannot afford to spend for a water power plant and the transmission system that must go therewith, an amount much more than $60.00 to $80.00 per kilowatt in excess of what a steam plant alone would cost to perform the same service. As the load-factor increases the allowable excess in cost of water power plant over steam increases because the fuel consumption becomes

higher with an increased load-factor. Even at a maximum load-factor that might be obtained in practice, however, a limit of cost is soon reached beyond which it is impossible economically to use water power.

A discussion by Mr. H. G. Stott followed lines very similar to those of Mr. Towniey's. Mr. Stott showed that maximum economy could be secured by combining steam and water power, the water power taking the high load-factor part of the load and the steam carrying the peaks.

Mr. John Martin, who was very largely instrumental in the early development of the hydro-electric plants now feeding the San Francisco region, stated that the Pacific Gas & Electric Corporation depended primarily on steam for their supply of power and that their water power might be regarded as fuel.

Mr. H. W. Buck drew attention to the popular error as to the profits of water power companies and stated that even the best of water power developments could not begin to compete with steam power if the cost of coal were as low as $1.00 to $1.50 per ton.

The general tenor of the whole discussion was to deny the popular fallacy that power may be furnished by water at rates much below those for steam and that the popular assumption of a "water power trust" is entirely unwarranted. It was manifestly the general opinion that until the cost of fuel rises to a value considerably higher than at present there can be no such thing as a general substitution of water power for steam. This is particularly true throughout the Eastern states, where coal is comparatively cheap and where water power developments are apt to be expensive and subject to wide variations of stream flow.

The relation of the points brought out in this discussion to the ever-present topic of "Conservation of Natural Resources" is an important one. Power produced from steam means the using up of a certain amount of fuel that can never be replaced. Once used this fuel is gone forever and there will be just so much the less for the use of future generations. The use of power derived from water, on the other hand, means the conservation of a certain amount of fuel which would otherwise be used. It follows, therefore, that a proper consideration for claims of future generations upon fuel supplies, if for no other cause, demands encouragement to the end that power developed from water shall occupy the whole of its legitimate field. The discussion of Mr. Doherty's paper shows that it is a prevalent idea among engineers

that such proper encouragement is being largely withheld at the present time on account of existing Government regulations.

It may properly be urged that future generations have a legitimate claim upon the water powers, as well as the fuel beds, and that no action of the present generation should prejudice this claim. There is, however, this all-important difference between a fuel-bed and a water power; the former once used is lost for all time; the latter, so long as it remains unused, is lost for all time; the former can wait *in statu quo* indefinitely, the latter should be developed to its full legitimate limit *instanter.* The situation calls for such governmental action as will stimulate immediate development of water powers. In this manner only can true conservation be secured.

P. M. LINCOLN

The Melville-Macalpine Reduction Gear

The most striking feature of the new spur-wheel reduction gear for high-speed steam turbines, which is attracting such wide attention, is its simplicity. There is no novel chain drive; no electrical nor hydraulic auxiliary. At first sight it is simply a common double helical gear of ordinary form. The supplemental element adds nothing to the principle of the gear, but is simply a means of overcoming the difficulties of the ordinary gear. The difficulty in a large gear does not lie in its ideal normal action, but in the impossibility of securing and maintaining the necessary mechanical perfections; hence, internal and abnormal forces result in friction, destructive wear or breakage. Obviously, if some device could provide a flexible or automatic adjustment which would do away with these internal stresses, a large high speed gear would be practicable. Apparently it was some such reasoning as this that led to a simple solution of the problem and produced the unexpected and almost incredible results which have been obtained. It is interesting to note that a gear with ten percent loss was considered admissible, that the arrangement for testing the present gear had been made suitable for the measurement of a loss of about five percent, and that these methods had to be modified when the loss was found to lie between one and two percent.

So simple a thing as a large spur-wheel gear may not at first sight appear of unusual consequence or excite enthusiasm. There are, however, several notable conditions which are involved. The

gear concerns the efficient generation of power in large units. The industrial and commercial progress of the past century has been dependent upon the generation of power and each new step in the means for producing and transmitting power has opened up new fields of activity.

The steam turbine has had two fields of application—the electric power house, where it has, in a few years, almost wholly superseded large reciprocating engines; and high speed vessels. In the latter the turbine has been run at an inefficient speed, and yet it is taking the place of the reciprocating engine; now, the more efficient turbine and gear are applicable to both high speed and low speed vessels.

In ocean traffic the sailing vessel began to be supplemented by the steam ship with a simple steam engine some eighty or ninety years ago. About 1865 the compound engine opened the way for a new class of ocean-going vessels. The triple expansion engine followed some twenty years later, giving new power capacity and enabling larger sizes of vessels and higher speeds to be attained. About ten years ago the turbine was first introduced for marine purposes, and soon came the Lusitania and the Mauretania. When the Great Eastern was built in the fifties, it was a practical failure because its machinery and its fuel took so much room that there was little left for cargo—although much smaller than the Lusitania, it required more than twice as much coal.

In this new gear the simple "floating frame," which allows the automatic alignment of the pinion shaft, has removed the old limits of size and weight and efficiency in the prime movers which have been the controlling factors in steam navigation. One of the most striking features of the presentation by Mr. Westinghouse is the summary of the indirect advantages in construction, economy and cargo capacity which are made possible in the design of vessels under the new conditions.

In the electric power station, the electric generator and the electric system transform the enormous power of the turbine, run at its most efficient speed, which is quite unsuited for direct application, and transmit and distribute the power in small units at moderate speeds for ordinary and varied service. On shipboard transmission and distribution are not required, and electric machinery would be cumbersome and heavy. The gear is the adjustable link which allows the turbine and the screw

each to work at its own best speed. Each is free and unrestricted; the old limits are removed and a new era of possibilities appears in marine construction, where tens of millions of horse-power require annually tens of millions of tons of coal in the international commerce of the world. The reduction gear may be a factor in the conservation of natural resources. On land, the development of water-power saves the consumption of coal; on sea, fuel alone can be used, hence the only way to save coal is by higher efficiency in its use.

The reduction gear is, of course, suitable for other applications than those on shipboard. A promising field is the operation of large, slow-speed, direct-current generators by high-speed turbines, as the direct-current generator does not readily lend itself to high speeds in large sizes.

CHAS. F. SCOTT

Portland Cement and Its Uses

The increase in the use of Portland cement during the past ten years has been marvelous. In the United States the total production in 1890 amounted to 335 000 barrels. In 1900 the output had grown to 8 480 000 barrels; in 1908 to 51 000 000 barrels, and in 1909 it will probably reach 55 000 000 to 60 000 000 barrels. In ten years the increase has been approximately 1 400 percent. Portland cement of a very high grade is being manufactured in all parts of the United States, including states bordering on the Atlantic and Pacific Oceans, the Gulf of Mexico and the Great Lakes, thus minimizing transportation costs and aiding in its universal adoption as a superior material of construction.

A large amount of study has been given to the proper component parts, methods of manufacture, treatment, storage, etc., until the products now upon the market may be expected to give fairly uniform results. Ten years ago it was customary to order cement by brands known to the trade, but to-day this plan of ordering has been changed. Practically all large users are purchasing cement on specifications and testing each shipment before placing it in any important construction. The American Society for Testing Materials has adopted a specification for Portland cement which is very largely used and which has been found to meet the general requirements of cement users.

The use of Portland cement has been extended from that of foundation work (its principal use in 1890) to buildings of either

brick, block, plaster or monolithic wall construction, shingles for roofs, reinforced concrete floors, waterproof concrete for cellars, cisterns, caissons, flat boats, floors for steel passenger cars, etc. It is also ued for fence posts, sewers, silos, culverts, tile, bridges, sidewalks, street pavements, blackboards for school houses, storage bins, dams, chimneys, telephone and telegraph poles, towers, ornamental work, tunnels, piles, switchboards and for innumerable other purposes where its particular adaptation has found favor.

Cement construction has a very remarkable fire-resisting quality, and where used it has been found to reduce fire risks sufficiently to affect insurance losses to a very great extent. A recent development along this line has been to fasten expanded metal or some other form of reinforcing to the outside of frame buildings and plaster a concrete coating on it. It is claimed that this gives added warmth to the building, as well as rendering it practically fireproof from the outside.

It has been demonstrated that concrete will stand a great deal of heat, but it has also been found that when cement or concrete is heated to a high temperature it is perceptably reduced in strength and increased in brittleness while hot, but upon cooling the original strength is practically all restored.

A slab of concrete may safely be heated to 200 degrees C. for a sufficient length of time to dry out every particle of moisture; when, by proper impregnation, it may be made into a good insulator and the very fact of easy molding suggests a coming use for cement for electrical as well as heat resisting purposes.

The article in this issue of the JOURNAL, on "Concrete in Electrical Construction," by Mr. Muller, is timely and may serve to illustrate further how far-reaching the use of cement has already become, and suggest a much more extended use for it in all fields of engineering.

T. D. LYNCH

Electric Power for Metal Mining

Whether it is a matter of deciding upon the kind of motive power to adopt for a new installation or the changing over of an old one, the two questions which at once present themselves to the manager are:—What will be the initial cost, and which will be the most economical to operate. The question of greater convenience and output, with the corresponding improvement in efficiency which is almost invariably secured by the introduction of electric motive power, is rarely thought

of, especially by managers who have never operated properties employing electric drive. It is perhaps but natural for one to shrink from adopting a class of power when he is not acquainted with the details of its working, and fall back on steam which he knows will do the work, even though at double the horse-power cost.

It would be interesting to know the number of power plants, operating to-day, in all classes of industries, by steam generated by comparatively expensive fuel, which might be developing the same power on one-half to one-third the amount of fuel by the use of gas producers and engines or by utilizing available water-powers and electric transmission, were the managers more familiar with the gas engine and the electric motor. While the expense of making the change, or the initial cost in a new installation, is most frequently given as the reason for not using electric power, the real reason, though not so acknowledged, more often is unfamiliarity with any other source of power than steam. The more progressive managers are willing to take the trouble to familiarize themselves with the opportunities presented by the new sources of power and they generally discover that it is a matter of months, not years, for the fuel economy to cover the expense of equipment.

With mining properties the power cost is one of the most important factors, especially where fuel is scarce and correspondingly expensive, as in the Western States and Mexico; and this item alone may determine whether a mine is to run at a profit or be compelled to close down. Water-power is not always available to drive a mining mill directly, but electric power can be used to transmit it for long distances; furthermore, many properties which have had to stop work on account of the expense of steam power could operate at a profit on producer gas and engine.

In mining, electric power has been successfully applied to such operations as hoisting, hauling and drilling, as well as lighting and the driving of pumps and ventilating apparatus. It gives unparalleled ease of control in the operation of machinery and imposes no restrictions either upon the location or the character of the driven apparatus. Electric wires may be run anywhere and under any conditions to be found in a mine. They are easily and quickly placed, occupy small space, and may readily be tapped wherever it is desired to operate machinery. In contrast with other means of power transmission, electricity does not require isolated boiler and engine plants, with long, inflexible and costly lengths of piping, nor does it involve complicated or troublesome mechanisms which

are costly to attend and maintain, but it does make possible considerable saving through the utilization of water-power or the consolidation of independent plants.

There are other economies which do not appear by a mere comparison of electric haulage with steam, compressed air, or mule traction; electric pumps with steam or compressed air pumps; electric hoists with steam or compressed air hoists, etc., but which result from the extreme general flexibility and applicability of the electric system, making possible the centralization of the power generating plant, the laying out of the mine in the manner most conducive to economical working, the improvement of mine conditions, decrease in the number of men required to operate boilers, engines, pumps, blowers, etc., a reduction in the cost of repairs, the installation of hoists, blowers or pumps at points where they would otherwise not be used on account of distance from the central power plant, the avoidance of the objectionable exhaust from steam engines, a saving in space requirements for machinery in general, and finally, the provision of safe, efficient and economical means of lighting the mine.

In the article in this issue by Mr. C. V. Allen a large amount of instructive information is given regarding the application of electricity to metal mining. Mr. Allen has had an extensive experience in mining work, especially in Mexico where he has aided in the introduction of electric power in many large mines and at the same time secured for their owners very considerable savings in operation.

BROADENING THE FIELD OF THE MARINE STEAM TURBINE*

THE PROBLEM AND ITS SOLUTION

GEORGE WESTINGHOUSE

ABOUT six years ago, Rear-Admiral George W. Melville, ex-Engineer in Chief, U. S. Navy, and Mr. John H. Macalpine, consulting engineers, undertook at my request a thorough investigation of the then existing status of the steam turbine as applied to the propulsion of ships, and the probabilities of its becoming the ultimate successor of the highly developed types of reciprocating engines commonly used for that purpose.

The data gathered in the course of the investigation and the conclusions drawn therefrom, were embodied in an exhaustive and interesting report which was delivered to me by its authors in May, 1904. Because of the universally recognized high standing of Admiral Melville and his associate as authorities in matters pertaining to marine architecture and engineering, and because the report was such a complete, temperate and logical exposition of the marine steam turbine situation at that time, I considered the information collected was of more than passing personal interest, and I had a limited number of copies of the report printed for private circulation, in order that others might benefit by a plain, dispassionate statement of fact, stripped of the fanciful embellishments with which a novel departure from established lines of practice is apt to be adorned unconsciously by over-enthusiastic advocates.

The report of May, 1904, was not of a very encouraging nature, but in the few years that have intervened, there have been developments which effect a radical change in the situation existing at that time. The most significant statement in the report of May, 1904, is to be found in the conclusion. It reads as follows:—

"If one could devise a means of reconciling, in a practical manner, the necessary high speed of revolution of the turbine with the comparatively low rate of revolution required by an efficient propeller, the problem would be solved, and the turbine would prac-

*This historical review and description of the Melville and Macalpine reduction gear for marine turbines is from the introduction to a pamphlet with the above title and is reprinted by permission of Mr. Westinghouse from the advance proof sheets.

tically wipe out the reciprocating engine for the propulsion of ships. The solution of this problem would be a stroke of great genius."

There could be no greater tribute to the far-seeing and well-balanced judgment of the authors of this report, than the fact that nearly five years later this identical sentiment was publicly voiced not only by Mr. James Denny, of Denny & Brothers, Dumbarton, Scotland, the oldest and most experienced builders of turbine propelled vessels in the world, and the most consistent advocates of the system, but also by the Honorable Charles Algernon Parsons himself, by whose brilliant creative imagination, the basic idea of the modern marine turbine was conceived, and by whose courageous initiative it was made an accomplished fact.

The parallelism of thought is so unusually striking that I quote the utterances of Mr. Parsons and Mr. Denny verbatim, as reported. Mr. Parsons in concluding his James Watt Anniversary lecture, delivered at Greenock, Scotland, on January 15th of last year, said:—

"We might naturally speculate as to the future, and inquire if there is a possibility of the turbine being constructed to run more slowly, and without loss of economy, or whether the propeller can be modified to allow of higher speeds of revolution. Or, again, may the solution be found in reverting to some description of gearing —not the primitive wooden spur gearing of half a century ago, but to steel gearing cut by modern machinery with extreme accuracy and running in an oil bath, helical tooth gearing, or chain gearing, or again, some form of electrical or hydraulic gearing? These are questions which are receiving attention in some quarters at the present time, and it a satisfactory solution can be found, then the field of the turbine at sea will be further extended."

Mr. Denny, in his Presidential Address to the Institution of Marine Engineers in Britain on October 5, 1908, said:—

"It has frequently been suggested that if some inspired engineer could evolve a system of gearing that would be lasting and reliable, not too noisy, and would not absorb in friction more than, say, ten percent of the power, turbine engines would be capable of application to any speed of vessel, and to any size of propeller; you would then have a high speed turbine and a low speed propeller, which is the ideal condition for marine propulsion."

The problem, first recognized by Messrs. Melville and Macalpine and the importance of which has since been admitted by Mr. Denny and Mr. Parsons, has been solved. It has been solved by

Messrs. Melville and Macalpine themselves, so that by one of the amusing freaks of fate, the compliment to the then unknown solver, implied in the last sentence of the paragraph quoted from their report of May, 1904, comes back to rest upon its unsuspecting makers.

The desired end has been accomplished by means of a reduction gear, which makes possible any reasonable speed ratio between the turbine shaft and the propeller shaft. It was no easy task to design a system of gearing that will operate quietly and without destructive wear at the speeds common to steam turbines of the highest efficiency, and at the same time be capable of transmitting thousands of horse-power. The details of the design that has proven itself capable of fulfilling these requirements, are fully set forth in an able and comprehensive article in *Engineering* (London, September 17, 1909), which is based on data supplied by Messrs. Melville and Macalpine. However, a few additional words of a non-technical character, generally descriptive of the gear, and indicative of its significance as a factor in marine construction, will not be out of place.

The teeth of the gears are helical, that is to say they do not run straight across the face of the wheel parallel to the axis, as in the case of ordinary spur gears, but they are cut in the form of a steep spiral, like an exaggerated screw thread. This construction allows the teeth to roll into contact without shock or jar. If there were only a single gear on each shaft this helical form of tooth would cause an objectionable end thrust. As the gears must be very wide to transmit the enormous power required in marine service, two gears, each of half the required width, are placed on each shaft, with the spirals of the teeth running in opposite directions. In this way the end thrust due to the obliquity of the teeth is completely balanced. With a pair of wide-faced gears with straight teeth, it is hardly possible to cut the teeth with such accuracy and to align the shafts so perfectly as to get uniform contact throughout the entire length. Even if it were possible to secure the requisite degree of accuracy at the outset, it could not be permanently maintained on account of the natural wear of the bearings. In general, the conditions are such that a rigidly confined set of gears, such as are common for moderate speeds and powers, is altogether inadmissible.

In the design which has proven its sufficiency under severe and exhaustive tests, the smaller gear or pinion is mounted in what the inventors call a "floating frame." The frame which carries the bearings for the pinion is a heavy casting, supported only at a single

point midway between the bearings. This support is flexible, so that the frame is free to oscillate in a vertical plane passing through the axis of the pinion, but is held securely against motion in any other direction. Furthermore, the pinion is free to move endwise in its bearings. Any tendency of the teeth to bear harder at one end of the gear than the other, would tend to unbalance the respective end thrusts due to the right and left hand spirals of the teeth; but as the pinion cannot present any resistance to unbalanced end thrust, it constantly adjusts itself in the direction of its axis to the position corresponding to equilibrium between the opposing forces. This means that the tooth contact pressures are always automatically equalized.

If there are any minute irregularities in the spacing of the teeth, which would tend to make the contact harder at one point than another in any part of the revolution, this tendency is defeated by the floating frame, the position of which about its central support or fulcrum is controlled solely by the pressures of the teeth of the pionion against the teeth of the large gear. Naturally, the floating frame always yields under the slightest tendency of an unbalanced contact pressure in such a way as to transfer the smallest increment of unbalancing pressure to another section of the gear, that in the absence of the floating frame would be less inclined to take its full share of the stress. In short, the gears are self-adjusting to relieve and equalize all abnormal strains, and are consequently independent of the small inaccuracies that it is impossible to eliminate in the best commercial manufacturing operations.

The probable efficiency of the gear was naturally the most anxious question, as the operating conditions were so wholly unprecedented that there were no existing data to enable one to even hazard an estimate. The effect of a low efficiency would be more serious than a mere impairment of the economic performance of the installation, as the transmission losses would manifest themselves in heating and destructive wear that would mean hopeless failure for the scheme in its entirety.

In order to definitely settle the question as to the practicability of the gear, it was necessary to devise methods, and to design and construct special appliances for testing it under all of the conditions of load and speed that would probably obtain in actual commercial service. The dynamometer for applying and measuring the loads to which the gear was subjected, will, I trust, be considered suf-

ficiently novel and interesting to warrant the extended description that will be found in another part of this publication.*

Considering the important bearing of the question of efficiency on the ultimate success or failure of the gear, it is peculiarly gratifying to have found by repeated trial and careful measurement, that the transmission loss hoped for by Mr. Denny, has been divided by seven. To be exact, the efficiency surpasses the more than satisfactory figure of 98.5 percent, a result that is without doubt inseparably connected with the flexibility and self-adjusting character of the apparatus.

It is needless to say that the gear is enclosed in a substantial casing, that adequate means are provided for its constant and efficient lubrication, and that the ingeniously designed connection between the gear and the turbine effectually prevent the self-adjusting movements of the pinion from communicating any longitudinal or transverse stresses to the turbine shaft.

Now that the mechanical operation of the gear is no longer a matter for speculation, it is interesting to consider its bearing on the design of turbine installations in ships.

The turbines of the giant Cunarders, *Mauretania* and *Lusitania,* are supposed to be capable of developing 70 000 shaft horse-power. Even the comparatively low speed at which these turbines run is too high for maximum propeller efficiency. It is hardly possible that the propeller efficiency exceeds 55 percent, which means that the actual effective propelling power is only about 38 500 horse-power. At a lower speed of revolution, well within the capabilities of the reduction gear, a propeller could be made that would have an efficiency of not less than 65 percent. With this improved efficiency, the shaft horse-power required for the same effective propelling power would be somewhat less than 57 000, a saving of about 15 percent. This means that without sacrificing in the smallest degree the remarkable speed of these vessels, the boiler equipment could be reduced about one-seventh, as well as the amount of coal burned on each voyage This would not only result in a very marked saving in capital investment and operating expenses, but would add many tons to the cargo-carrying capacity, and add correspondingly to the earning power.

But this estimate large as it is, is still too modest. With the turbine and the propeller direct-connected so that both revolve at

*It is planned to publish this description in the next issue of the JOURNAL.

the same speed, not only is it necessary to sacrifice the efficiency of the propeller, but the efficiency of the turbine as well.

For equal efficiencies in any two turbines, the number of rows of blades is, roughly speaking, inversely proportional to the squares of the respective peripheral speeds of the rotating elements. The peripheral speed of the rotating elements in the turbines of the *Mauretania* and *Lusitonia,* is only one-third of the speed common in large turbines used on land. This would mean that to obtain the efficiencies common to the latter, the former would require approximately nine times as many rows of blades, which would make a machine of prohibitive length. To maintain the same speed of revolution and increase the peripheral speed of the turbines of these vessels to the point common in land practice the rotors would have to be nearly forty feet in diameter, which is manifestly beyond the shadow of possibility.

From the best information obtainable, it is believed that the steam consumption of the turbines of the *Mauretania* and *Lusitania* cannot be less than 14.5 pounds per shaft horse-power per hour, while it has been demonstrated beyond question that with turbines of similar capacity operating at speeds which the reduction gear makes possible for marine service, the steam consumption does not exceed 11 pounds per shaft horse-power per hour. This means that the boiler capacity could be further reduced from the first estimate of 60 000 horse-power to about 45 000 horse-power, and the overall efficiency of the installation would be sufficiently improved to result in a reduction of over 35 percent in the coal consumption. It is unofficially reported that the coal consumption of these vessels is about 4 700 tons per voyage. Reckoning the cost of coal at $3.25 per ton, the saving in coal alone would be $5 300 per voyage, to say nothing of the smaller cost for wages and sustenance for the lesser number of stokers that would be required. The increased cargo capacity resulting not only from a reduction of over 1 600 tons in the coal required to be carried on each voyage but also from the greatly reduced weight of equipment, and the space necessary for it, is an asset the value of which it is difficult to over-estimate.

If greater speed would be regarded as more attractive than the possible economies mentioned above, it is easy to see that with the same boiler capacity as is now installed in these ships, the better economy of the high speed turbine would make it practicable to use much more powerful propelling machinery without increasing

the amount of coal consumed. The additional power on the turbines, together with the greater propeller efficiency that is possible, would easily give the increased speed that would insure the disembarking of transatlantic passengers on the fifth day with certainty and regularity, instead of only on occasions when all of the conditions are unusually favorable.

The *Mauretania* and *Lusitania* have two high pressure and two low pressure turbines, and two reversing turbines working on four shafts. According to the best information obtainable, the high pressure turbines have each 128 double rows of blades, and the low pressure turbines 60 double rows each. The total length of the blading, exclusive of the relatively small amount in the reversing turbines, is about 115 miles, and the total surface area of the blades is considerably more than three-quarters of an acre, or equal to the sail area of a large ship.

By using the reduction gear, the same total propulsive power could be installed in three turbines. There is nothing problematical about this statement, as turbines developing the requisite power, and of the same general design as would, in connection with the reduction gear, be suited to marine work, have been operating successfully for a long time, and their power and economy are now matters of authentic record. Each turbine would have only 51 double rows of blades, a total in the three turbines of 153, or only 25 in excess of the number of rows in one of the high pressure turbines alone in the present installations on board the Cunard flyers. The total length of the blading in the three high speed turbines would be less than six percent of that in the low speed turbines.

Each shaft would be driven by a complete and independent self-contained turbine, and each shaft would have its own reversing turbine, so that the entire screw equipment would be available for backing instead of only one-half of it, as is the case in the present arrangement.

However much the new system promises for express steamers in the mercantile marine, it has vastly more important advantages as applied to naval vessels. The express steamer normally runs at its highest speed, and this is the condition for maximum turbine efficiency. This is especially true in the case of turbines connected directly to the propeller shaft, for the reason that, as outlined before, the peripheral speeds and number of rows of blades are at best below the requirements of efficient design, and any dropping below

the maximum working speed accentuates the bad effect of this deficiency.

On the other hand, in the case of a battleship or a cruiser, maximum speed is only an emergency condition. The normal cruising speed is only about 60 percent of the maximum speed, and requires perhaps less than 25 percent of the maximum power. It is at the cruising speed that turbine-propelled naval vessels have shown to disadvantage as compared with vessels propelled by the best types of reciprocating engines. By reason of the more liberal blading that is possible in a high speed turbine, its economic performance is less sensitive to departures from maximum rotative speed than is that of the low speed turbine. Furthermore, as the entire expansion of the steam takes place in a single turbine, the total power may be distributed conveniently among three entirely independent units, driving one central and two wing propellers. The central unit alone will suffice for ordinary cruising speeds, and can be operated always at somewhere near its most economical conditions of working.

In naval service, the ability to start the turbines when cold, and quickly bring them to full speed may often be of the very highest importance. With turbines directly connected to the propeller shafts, the lengths and diameters of the rotors and casings are such that in order to prevent serious distortion from unequal heating and expansion, it has been found necessary in practice to bring all of the turbine machinery to the normal working temperature before it may safely be set in motion. I have been informed by those having charge of turbine machinery on a large battleship, that the preliminary warming often requires some hours.

In the double-flow turbine which it is proposed to use with the Melville and Macalpine gearing, the smaller dimensions consequent on the higher speeds give a sturdier construction in which the tendency to distortion is reduced to a negligible minimum; and an elastic self-adjusting mounting for the stationary blades, easily removable for examination without unseating the rotor, compensates for any inequality in the expansion of the rotor and the casing, and effectually prevents the stripping of blades even if there should be actual contact between the stationary blades and the body of the rotor, or between the moving blades and the casing. With this construction, steam, even though it carries large quantities of water of condensation with it, may be admitted to cold turbines, and full speed obtained in less than a minute.

The United States Government has lately awarded contracts for two new battleships, to be equipped with steam turbines. These battleships are to have a speed of 20.5 knots, which will require in round numbers 28 000 shaft horse-power. With 55 percent propeller efficiency the effective propelling power will be about 15 400 horse-power. With the 65 percent propeller efficiency that is easily possible with the reduction gear and a propeller at a lower speed of revolution, this same propelling power would require less than 24 000 horse-power on the shaft. The average steam consumption guaranteed at full power is about 14.5 pounds per shaft horse-power. With the better steam economy of the high-speed turbine, the boiler capacity required would be reduced fully one-third. With the same bunker capacity, the radius of action would be enormously increased, which is an advantage of incalculable value.

If the same boiler equipment as is now proposed were maintained, there would still be a saving in weight of over 250 tons, or approximately one-eighth of the total penalty weight of the machinery in each ship, resulting solely from the substitution of the high-speed turbine and reduction gear for the more cumbersome slow-speed direct-connected machine. At the same time, by reason of the well known overload capacity of a liberally proportioned turbine, there would be available a surplus power of about 50 percent, which should make possible an emergency speed of nearly three knots in excess of that called for in the specifications.

Furthermore, the three independent shafts, each with its own self-contained turbines for going ahead and astern, would give the excellent manoeuvering qualities which are admittedly lacking in vessels fitted with the present conventional turbine equipment.

The certainty with which the floating-frame of the Melville and Macalpine reduction-gear operates to maintain an evenness of tooth-pressure and the limitation of the maximum pressure to 450 lbs. per inch of tooth-contact with a load of 6 000 horse-power, coupled with a large factor of safety, at once remove this invention from an experimental to a completely commercial apparatus.

I regard this invention as epoch-making in its importance. It has been my privilege to supply the material things which were needed to transform the creature of Messrs. Melville and Macalpine's imagination into an actual thing of iron and steel. The results achieved by the completed machine have fully justified my faith in its ultimate success.

DESCRIPTION OF THE MELVILLE AND MACALPINE SPUR-WHEEL REDUCTION GEAR

A definite idea of the appearance of the experimental installation and the principle of operation of the reduction gear may be obtained from the following illustrated description. The gear, enclosed in a case, is located between a steam turbine and a dynamometer, as shown in Fig. 1. The turbine developed 6 000 horsepower at 1 500 r.p.m. on test. The reduction ratio is five to one, giving a resulting speed to the dynamometer brake of 300 r.p.m.

Fig. 2 shows the gear alone with part of the casing and the top half of the floating frame removed. The pinions have 35

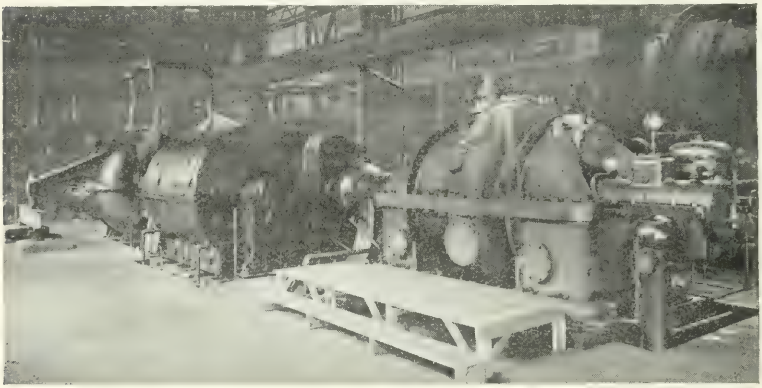

FIG. 1—GENERAL VIEW OF MELVILLE AND MACALPINE REDUCTION GEAR WITH STEAM TURBINE AND DYNAMOMETER, AS ERECTED FOR EXPERIMENTAL TESTS

teeth each, and the spur wheels 176, a hunting-tooth being introduced to equalize wear.

The pitch is 1¼ in., and the tooth helices are at an angle of 30 degrees with the axis of the shaft. One wheel and pinion have right-handed helices, and the other pair left-handed, so as to eliminate end-thrust. The diameter of the pitch circle of the larger wheels is about 70 inches and of the pinions 14 inches. The pitch line speed is very nearly 100 feet per second and the pressure on the teeth does not exceed 453 lbs. per lineal inch.

The mechanical perfection which would be required in an ordinary gear of these dimensions is beyond the practical limits of construction, and even if absolutely correct dimensions were once secured, they could not be maintained. The wear of the teeth would not be uniform and proper alignment could not be assured continuously on account of wear of bearings and the vari-

ation due to mechanical stresses or to unequal temperatures. It is the impossibility of securing and maintaining mechanical perfection which prevents the successful operation of an ordinary gear of these dimensions and for these speeds and which the novel arrangement in the present gear overcomes.

In order to allow the pinion and the gear to adapt themselves to one another automatically, the pinion shaft is given a freedom of motion in two ways; first, longitudinally, and, second, tangentially on the spur wheels. This permits the alignment and position of the pinion shaft to be controlled wholly by the

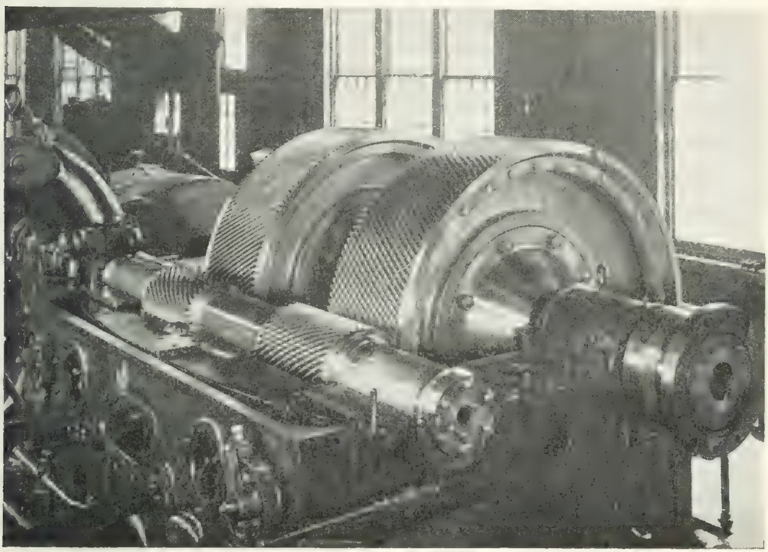

FIG. 2—MELVILLE AND MACALPINE REDUCTION GEAR
With top half of case and upper part of floating frame removed,

interaction of the teeth in contact, and not, for example, by the fit or alignment of the bearings. The arrangement for the longitudinal adjustment is shown in Fig. 3. This shows the pinion shaft with the two pinions, the three bearings, and at one end a coupling by which connection is made to the turbine shaft. This coupling consists of two flanges, mounted on their respective shafts and connected by two transverse links, one being shown at the top and one at the bottom in the illustration, and by a center pintle. The turbine shaft can, therefore, only rotate the pinion shaft through the two links, but as these are transverse, no longitudinal forces can be transmitted. The pinion, therefore, has

freedom of longitudinal movement in its bearings. Further, the pinion shaft is hollow and a second spindle or smaller shaft,

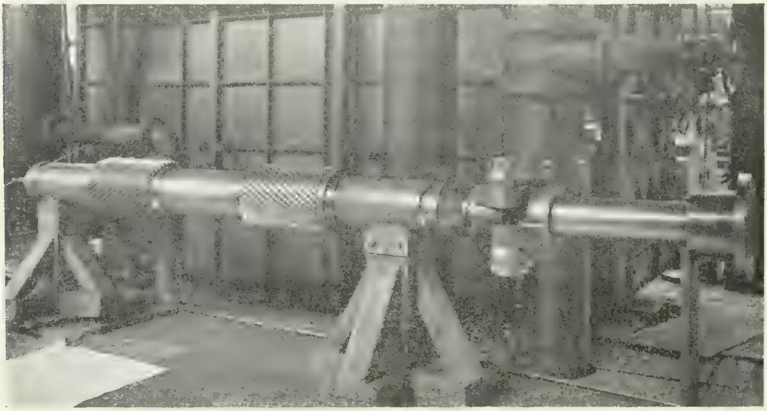

FIG. 3—PINION SHAFT AND COUPLING OF MELVILLE AND MACALPINE REDUCTION GEAR

The steam turbine shaft is connected to the flange coupling at the right. The link coupling connects to the driving spindle extending through the hollow pinion shaft and attached to it at the left. The flexibility of this link coupling and the spindle permits the automatic adjustment of the pinions to the gears.

which is the one directly connected to the coupling, runs through the hollow pinion shaft and is connected to it at the end remote

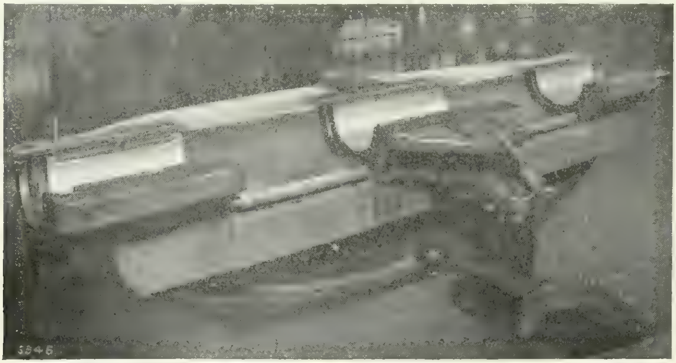

FIG. 4—LOWER HALF OF FLOATING FRAME OF MELVILLE AND MACALPINE REDUCTION GEAR

Showing the three bearings for the pinion shaft and one of the two I-beam supports. The "floating" of the frame is permitted by a slight flexure of the webs of the I-beams.

from the coupling, where it is keyed and bolted. This spindle is so flexible that it imposes practically no constraint on the pinion

and, therefore, allows the pinion shaft to change its direction slightly, so that one pinion may be slightly higher or lower than the other, without affecting the alignment of the inner shaft at it coupling end.

This freedom of motion is secured by mounting the three bearings of the pinion shaft in a floating frame, and arranging this frame so that it may turn or vibrate slightly around an axis passing through the pinion shaft mid-way between the two pinions.

The floating frame is massive and strong and is supported by two short I-beams, one of which may be seen in the fore part of

FIG. 5—MELVILLE AND MACALPINE REDUCTION GEAR
Top part of casing removed, showing the floating frame in place, pinion shaft removed.

Fig. 4. These I-beams are flexible enough to allow the frame to tip slightly, so that one end may be higher or lower than the other, thereby allowing the teeth of the two pinions to adjust themselves to the teeth on the spur wheels.

The upper half of the floating frame in its normal position is shown in Fig. 5. The upper and lower halves are substantially similar in form and give a rigid alignment for the three bearings of the pinion shaft. The actual motion at the ends of the pinion shaft is a very small fraction of an inch, but is sufficient to enable the pionions and spur wheels to adapt themselves to one another.

Although the two ends of the pinion shaft may rise and fall, yet the internal shaft, which runs through the hollow pinion shaft, is stationary at the coupling by which it is connected to the turbine shaft, on account of its flexibility, as above described.

A drawing of the pinion shaft showing the internal shaft running through the interior and connecting at one end to the coupling is shown in Fig. 6.

The strength of both the pinion and floating frame are far in excess of that which is requisite to sustain the maximum forces to which they will be subject, their dimensions being made to give ample rigidity. For instance, under full-load, the flexure of the cast-steel floating frame in the vertical plane is so slight that the end bearings will be lowered relatively to the center by not more than 1/2 000 inch. There is a certain compensation for this deflection, owing to the action of the lubricant. The thickness of

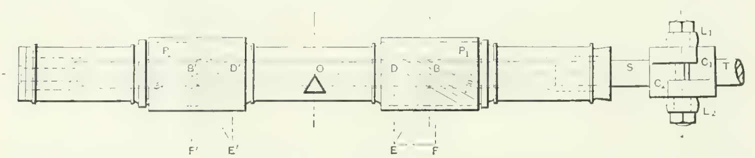

FIG. 6—SKETCH OF PINIONS AND SHAFT OF MELVILLE AND MACALPINE REDUCTION GEAR

The pinion is supported by three bearings, the centre bearing dividing the tooth faces P_1 and P_2; C_1 and C_2 are the two parts of the flexible coupling, joined by the transverse links L_1 and L_2, connecting the turbine shaft T to the spindle S, which is keyed and bolted to the pinion shaft at the left-hand end. The floating frame is free to rotate slightly around the point O as a centre by flexing the I-beams.

the oil-film is probably about 1/1 000 inch, so that a difference in the pressure in the three bearings, which would be occasioned by the flexure of the floating frame, will tend to be equalized by the difference in the thickness of the oil-films due to different pressures in the bearings. The design provides for a copious application of lubricating and cooling oil, especially to the pinion which has most tendency to heat. With a loss of, say, 1.5 percent, i. e., 98.5 percent efficiency, the actual heat generated in the gear will be about 90 horse-power when 6 000 horse-power is being transmitted. Obviously, this requires some means of carrying away the heat, and this is accomplished through the circulation of the oil. The cover is also arranged so that, if necessary, air may be drawn in at the ends and discharged by the fan action of the gears, thus assisting in cooling the gears and oil.

SOME APPLICATIONS OF CONCRETE AND CEMENT TO A CENTRAL STATION SYSTEM

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THE use of concrete and cement in connection with electrical structures has received considerable attention and its success as a new agent for this purpose is generally known. A description of some novel applications to various construction and repair work in a large central station system will illustrate its adaptabiilty to the various requirements of such a system. The methods described are, with one exception, original with this company.

REINFORCED SWITCHBOARD STRUCTURES

A novel and economical method of construction was used in the building of a reinforced cement switchboard structure for the Esplen sub-station of this system. This switchboard is so located that it serves as a junction point between the aerial and underground trunk cables to the various power houses and sub-stations of the company. No switches excepting the hook-type disconnecting and paralleling switches are provided. In all cases, excepting in emergency, each cable continues through to its destination without any inter-connection with any other cable at this or any other sub-station, with the exception of one cable intended to supply the overhead lines which can be considered as feeders radiating from the station and carrying much smaller individual loads. These feeders, however, are each provided with oil circuit breakers, as shown in Fig. 1, which is an interior view of one section of the Esplen sub-station.

The principal feature in which this cement switchboard structure varies from other concrete switch and bus-bar structures, lies in the fact that all of the structure excepting the base was plastered on metal lathing (expanded metal) instead of being poured, as is the common practice. The metal frame work, consists of three by three inch angle irons running through the center of the board, one at each end and one located at each of the main sub-divisions between each three-phase panel, i. e., every third vertical compartment. The small channels are of one-inch size. Over these is stretched the expanded metal, which is of

about 1 by 3/8 inch mesh, and is tied with iron wire to the framework. A section of switchboard structure ready for plastering is shown in Fig. 2. The switchboard, as shown, is braced to the wall with four-inch channels which, however, are used only during construction and are not necessary for the support of the board after erection.

This structure is two feet, six inches in width, the central vertical web being three inches thick; the barriers in the rear project 12 inches and the barriers and shelves in the front 15 inches; the barriers between adjacent wires are two inches thick and between each circuit of three wires, three inches thick. The foundation, which was poured, was a 1-2-4 mixture. The entire structure is strengthened lengthwise by means of two 80-lb. T-rails. This stiffening was deemed advisable to permit of spanning a manhole and to guard against trouble from possible settling of an unstable earth foundation. A cement mixture, consisting of one part Portland cement, two of sand, 50 percent lime, with one bushel of hair to each barrel of lime, was first applied by a plasterer's trowel; the second and third applications being one part cement to three of sand, with no lime and no hair.

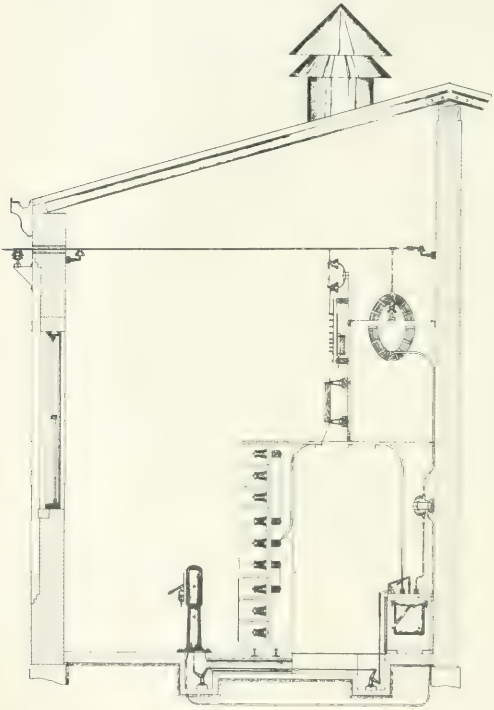


FIG. 1—SECTIONAL VIEW OF 13 000 VOLT SWITCHBOARD STRUCTURE AT ESPLEN SUB-STATION

The greatest thickness of any web or barrier is three inches, and it was necessary to make only three applications of this composition to obtain the desired thickness in any plane. As a finishing coat, it was given a skim of about one-eighth to one-quarter inch of Keene's cement, a hard white surface thus being obtained,

which made a good bond with the body cement and resulted in a very pleasing appearance. The thickness of the Keene's cement was varied where necessary to correct any unevenness in the surface. Rough holes were left where the porcelain insulator supports were to be mounted; these were trimmed out and the insulators were then grouted in with cement, as shown in Fig. 3 which is a view of a section of completed switchboard and bus-bar structure.

A question naturally arises as to the relative merits of constructing a switchboard in this manner as against the usual method of pouring the concrete. This is a problem which varies with individual cases. As some of these two-inch vertical barriers are nine feet long and 12 inches wide (See Fig. 4), considerable trouble was anticipated, due to the tendency of the boards to warp or spring out of position. The work of construction was carried on without difficulty, however, and, during over two years of service, the structures have shown themselves to be in every way as substantial and satisfactory as similar structures built by the method of pouring into forms.

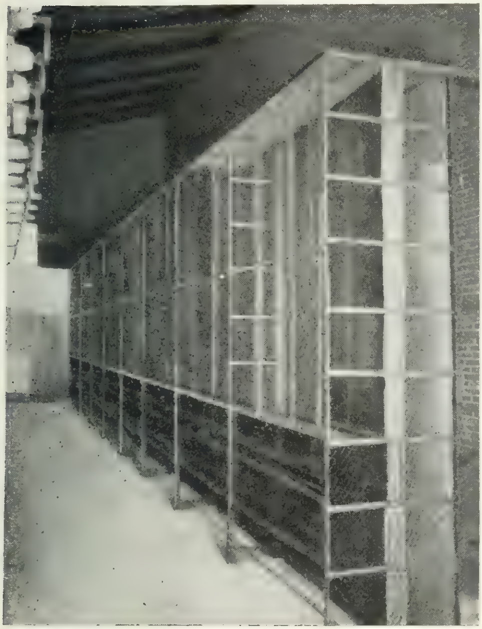


FIG. 2—METAL FRAMEWORK AND EXPANDED METAL REINFORCEMENT, ON WHICH THE CEMENT IS PLASTERED TO FORM THE SWITCHBOARD STRUCTURE

Where structures require heavier sections and where "knockdown" forms could be repeatedly used, it would probably be cheaper to pour than to build up by plastering; but, as a comparison, in this case, the builder's estimate of the cost of construction of the structure by the former method may be cited. For the lumber and labor for making the forms and putting them in position, exclusive of material, and cost of mixing, pouring and

finishing, the estimated expense was alone two-thirds of the cost of this entire completed switchboard without the electrical apparatus. In this connection it might be interesting to state that it was found that the cost for slate at the quarry for use in place of concrete would likewise run about the same as the builder's estimate for making the wooden forms. An approximate estimate gives at least twice the cost for pouring this switchboard as compared with the expense of applying the cement with trowel. Erection of the iron work and stretching the expanded metal is a very simple operation, and, with the services of a plasterer and a man to mix the cement, the work is easily carried through with surprising speed and without the necessity of any previous experience.

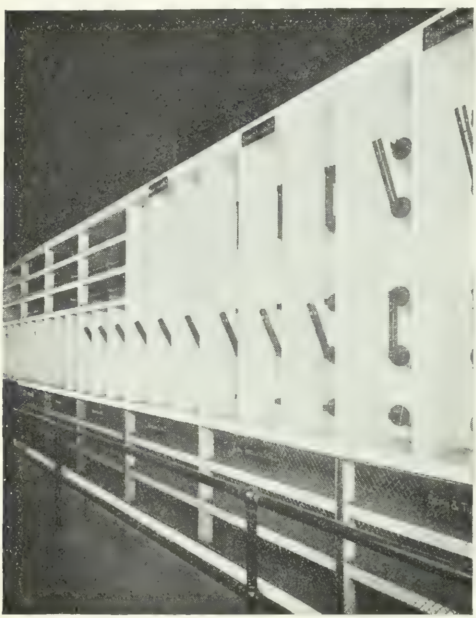


FIG. 3—BUS-BAR AND SWITCHBOARD STRUCTURE COMPLETE AND EQUIPPED

The bus-bars and switches are mounted on porcelain insulators cemented into the structure, which is built up as shown in Fig. 2

The bus-bars and disconnecting switches are mounted upon porcelain insulator supports, which in turn are cemented into the switchboard; "rear connected" type switches are used where the conductors are to be carried through the barriers, an arrangement which is both simple and satisfactory.

REINFORCED CEMENT SHELVES IN MANHOLES

In an underground system where cables are carrying from 2 000 to 5 000 kilowatts, damage to such cables becomes a matter of serious consequence, and their protection from mechanical injury, especially in manholes, is very important. For this purpose the Allegheny County Light Company designed octagonal shaped

manholes, receiving but two cables on the same horizontal plane, one turning to the right and one to the left, giving very gradual bends and resting throughout their length on reinforced cement shelves one inch thick. In the construction of these shelves expanded metal of one inch mesh is stretched in forms, into which the concrete is poured, a mixture of one part cement to two of sand being used. A plan and elevation of a cable manhole of this type is shown in Fig. 5.

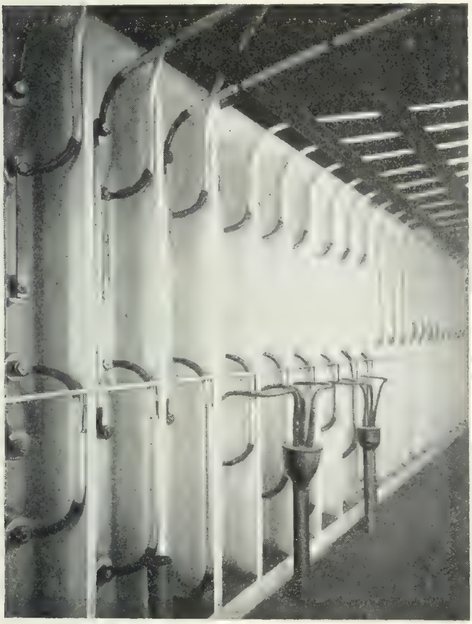


FIG. 4—CONCRETE STRUCTURE AND CONNECTIONS AT REAR OF CIRCUIT BREAKERS, SHOWING LINES ENTERING HIGH-TENSION CABLES

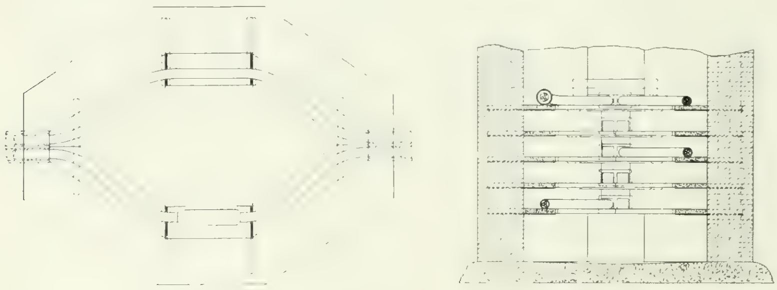
The shelves are removable and are laid upon angle irons built into the manhole walls. These barriers protect the cables from being walked upon by careless workmen, or struck by ladders, falling tools, etc. They also are considered a protection above and below in case of severe short-circuit in adjacent conductors; moreover, the weight of the cables is quite uniformly distributed, which is a considerable advantage over the former method of supporting them from manhole cable-racks. These shelves cost about 10 to 12 cents per square foot. They need only be manufactured and added as the multiplication of cables in the conduit line warrants.

CEMENT CABLE ARMOR

Where many cables are brought into one chamber and where insufficient clearance or bends and turns make the use of barriers impracticable, as well as the expense prohibitive, a very effective protection is obtained by the application of cement directly to the cables. A cement armor is applied by first winding one-quarter

inch sisal rope spirally around the cable one-half inch between centers and applying a rather dry mixture of one part cement to two parts sand. The whole adds about three-eighths inch to the radius of the cable. The cement is applied by hand with leather pad and brush. The cost runs from one and one-half to two cents per linear foot, depending upon the location and diameter of the cable.

This armor has been found to be of considerable protection to cables in cases where they might be accidentally struck by tools, etc., and serves also to prevent the cables from being bent and twisted by men not conversant with the proper handling of this material. It is also expected that this will prove a protection from burning in case of short-circuit on adjacent cables, as it has



(a) PLAN (b) ELEVATION

FIG. 5—SPECIAL TYPE OF MANHOLE IN WHICH SEPARATE REMOVABLE CONCRETE SHELVES CARRIED ON ANGLE IRONS BUILT INTO THE WALLS ARE PROVIDED FOR THE CABLES

been found that a blow torch applied to a cable so armored stood about four and one-half minutes before the lead armor began to melt; whereas, without the cement the lead melted in about one-fourth this time. An illustration of the application of this method of protection to several conductors in a cable pit is given in Fig. 6.

Cement is considered superior to asbestos for this work, not only because of its giving a more rigid protection against mechanical injury; but also because a short-circuit in the cable will usually manifest itself by bursting the cement, while with asbestos protection short-circuits are often difficult to detect from any external appearances. Moreover, asbestos swells up when subjected to moisture and requires additional circumferential reinforcement to prevent its falling away.

FIRE-PROOF ENCLOSURES

It is often necessary to carry the 2 200 volt distributing circuits directly to such locations as lumber yards, basements of stores, public halls, residences and factories where accidental contact with the 2 200 volt circuit is possible, or where the danger from fire in case of blowing of fuses, or short-circuits in transformers is to be guarded against. The Board of Fire Underwriters requires fire proof vaults where any oil-cooled transformers are used on the customer's premises. In order to meet these requirements and afford a protection against personal injury, this company has developed a standard form of enclosure for transformers with their switches, fuse blocks and other special apparatus used in such cases. Reinforced concrete slabs of standard size are used for these structures. These are made by pouring the concrete into forms, the inside dimensions of which are six feet by three feet by two inches thick. Expanded metal of one and one-half inch mesh is used for the reinforcement of the slabs, it being stretched in the forms before pouring. Cores are placed in proper position to provide for holes used in assembling, for ventilating ducts, switch handle openings, etc. The slabs may thus be drawn from the forms ready for immediate assembling, except for cutting away the mesh from the various openings as required. The mesh is ordinarily allowed to remain in the ventilating openings.

FIG. 6—CEMENT-COVERED CABLES IN CABLE PIT

Method of armoring as a protection against mechanical injury. An effective means of localizing short-circuits.

In assembling the structure suitable angle iron, channel iron,

etc., is employed to join the various concrete slabs, ordinary bolts being used. By this unit system a transformer enclosure of any size can be built, the minimum of course being three by three by six feet. The foundations for these enclosures, when required, are formed by pouring the concrete, as this has been found to be the simplest and most satisfactory method of construction of this part of the structure. Iron doors are used for these structures, of such dimensions that, with their iron framework, they will replace one of the standard size slabs.

An installation of this kind for a 1 000 kilowatt oil insulated transformer, located in the basement of a department store, where

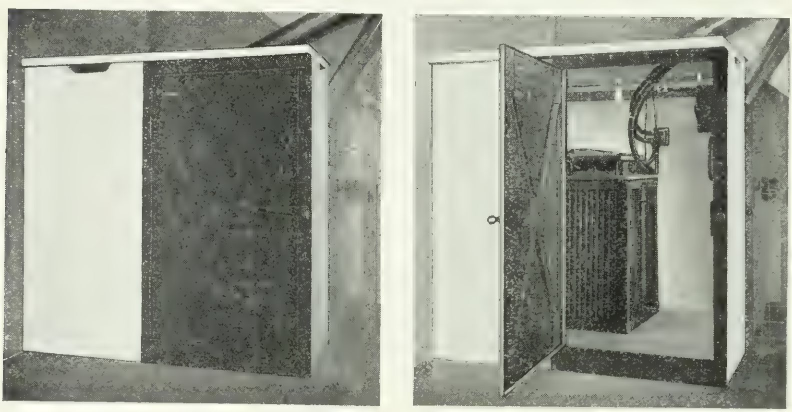


FIG. 7—TRANSFORMER CELL IN BASEMENT OF DEPARTMENT STORE, CONSTRUCTED WITH STANDARD REINFORCED CEMENT SLABS

The handle of the oil switch, the meter connections and the leads for the pilot light are the only wires that are not either enclosed in conduits or contained within the cell, which is kept locked.

all of the wires for over 100 volts are enclosed in conduits is shown in Fig. 7. The only wires accessible from the outside of the vault are the potential wires of the meter and the two leads for the pilot light.

In this and similar cases where two circuits are furnished, one for the regular lighting and one for emergency, a double-throw switch is mounted within the enclosure with the switch handle projecting through one of the slabs. A diagram of connections with instructions to the local electrician, as well as the integrating wattmeter, is placed on the outside. The pilot lamp serves to light the outfit and all apparatus the same as if the apparatus were mounted on a switchboard panel.

An enclosure of this type installed outside of a factory building is illustrated in Fig. 8. The roof is made of standard slabs covered with weather-proof material. There are 13 slabs in all; the general dimensions are six by nine feet by six feet high.

This fire-proof vault is divided into two compartments, one six by six feet, in which the oil insulated transformer, the tank of the oil switch and the primary fuses are located; the second compartment, three by six feet, encloses what might be termed the front of the switchboard, containing the switch handle and the meters. The first compartment is locked and the key kept by the

FIG. 8 — TRANSFORMER STRUCTURE EXTERIOR OF FACTORY

Made of standard reinforced cement slabs and iron doors which, with their frames, correspond in size to the standard size of slab.

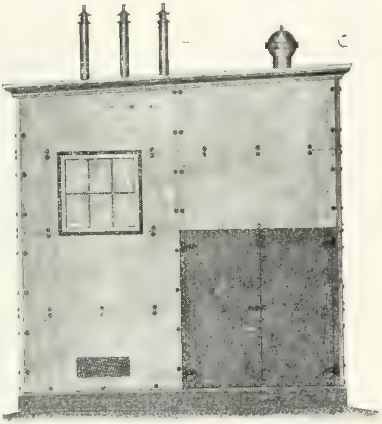


FIG. 9—TRANSPORTABLE SUB-STATION USING STANDARD CEMENT SLABS

Angle and T-iron of suitable dimensions is used to join the slabs. Provision is made for light and ventilation when the slabs are poured.

superintendent in charge of the district, while the low-tension compartment, containing the switch handle and meters is locked and the key kept by the electrician on the premises. This allows accessibility to the switches and the meter without danger of contact with the higher voltages

This company has made about ten installations in the last six months. The cement slabs are made on the premises of the company, which affords a rainy day job for the outside men. The cost of a standard sized slab is about $2.50; and the cost for the iron door, which is of practically the same dimension, is about twice this amount. These vaults are not only cheaper to install than one that would be poured on the premises, but they can be

readily taken apart and moved to a new location, or increased or decreased in size according to future requirements.

The extension of this idea, using standard sized slabs for the construction of a transformer sub-station is shown in Fig. 9. The framework of this proposed house is to consist of three-inch angle irons on the corners, and five by three inch T-irons for the center vertical supports and for carrying the roof slabs. The openings for ventilation below are obtained by placing a core in the forms, thus allowing the expanded metal reinforcement to show. The windows consist of wire-glass mounted in steel sashes

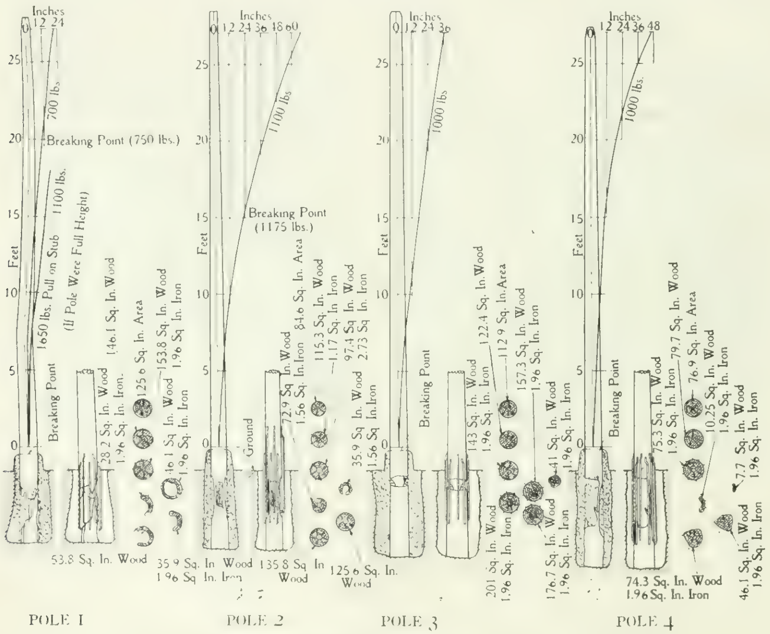


FIG. 10—POLES REINFORCED BY MEANS OF RODS AND CONCRETE

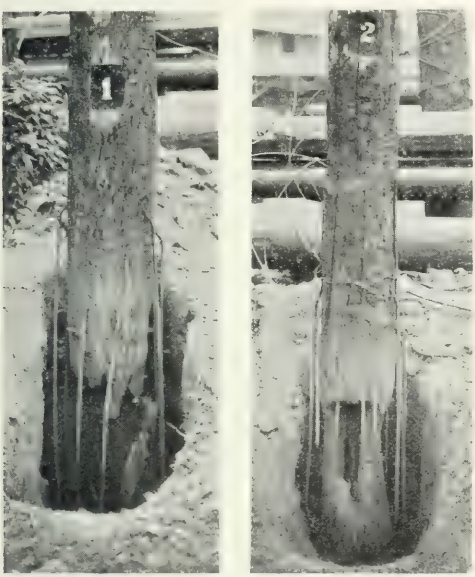
Poles *1*, *2*, and *4* have become weakened through butt rot, as shown by the cross-sections. Pole *3* is a new pole artificially weakened. After being reinforced, the poles were subjected to strength tests by applying a horizontal pull at a standard distance of 27 feet above ground. The point of failure, breaking load and deflections obtained are indicated for each case.

with an angle iron framework. The eaves are finished off with a metal cornice, and the roof slabs are covered with tar and gravel and are laid with a pitch of one-half inch to the foot. The whole outfit is portable, except the foundation, which is poured. The particular value of such a house is that it is very flexible so far as dimensions are concerned and can be cheaply erected; and, if future requirements warrant a more pretentious sub-station, this

house can easily be taken apart and erected elsewhere in its entirety, or otherwise used in smaller units. The cost of such a building is practically the same as one of the same size constructed of corrugated iron. The life of corrugated iron is short; it is easily bent and perforated, and it requires frequent painting. The difficulty of painting without interruptions of the high potential circuits is one to be reckoned with. Cement also lends itself much more readily to mounting apparatus than corrugated iron.

REINFORCING POLES

The method or repairing poles suffering from butt rot, by means of concrete reinforcement offers many features of value to the maintenance department of railway, lighting and transmission companies, in fact, of all systems employing wooden poles, which are subject to decay. Fig. 10 shows the general method of doing this work, but which is modified to meet the requirements of individual cases, and upon which patents were granted to Mr. R. S. Orr, who developed this process. The rods are of Bessemer steel, one-half inch in diameter and vary in length from four to six feet. One end of the rod is bent at a right angle; this short leg is driven into the solid part of the pole above ground level, while the other end is driven into the remaining sound butt. A 1-2.5-5 mixture of concrete is then thrown in around the pole, allowed to settle into the cavities and is finished off with a richer mixture at the exposed end above the ground. This upper end of the cast is given form and finish by the use of an adjustable form.



FIGS. 11 AND 12—POLES IMPAIRED BY EXTENSIVE BUTT ROT
Reinforced with rods (as shown in detail in Fig. 10)

Before this method of repair was applied to poles in service on the lines of the company, an investigation was made, to determine the effectiveness of this method of repair. Several poles which had been in service from 15 to 20 years and whose strength had become seriously impaired as the result of butt decay were carefully removed from service, reset and repaired by applying the foregoing method, using reinforcing rods and concrete. Tests were applied to prove their strength after being thus repaired.

FIG. 13—REINFORCED POLE UNDER TEST
View taken at instant of failure.

Figs. 11 and 12 represent two of these poles. The testing was done by applying a horizontal pull to the poles at a point about 27 feet above ground level, and all of the following figures referring to the breaking tests are based on this height and direction of pull. Pole No. 1 (Fig. 10) broke under a strain of 750 lbs. at a point 20 feet above ground, where it had been weakened by cutting a deep gain. The rope was then tied to the pole about 18 feet above ground, the failure occurring under a pull equiva-

lent to 1 100 lbs. applied at the standard height of 27 feet; the break occurred at the top of the reinforced collar.

Pole No. 2, as shown in Fig. 12, was reinforced with a supplementary set of rods owing to the large cavity which extended both above and below the point of extreme decay. These rods were driven into the sound wood above the hollow part and about three feet from the ground. Under test this pole failed at a point 15 feet above ground, the test load being 1 175 lbs. Fig. 13 shows the pole at the instant of failure.

In each of the preceding cases the poles broke above the concrete reinforcement, but pole No. 4 began to fail under a horizontal load of 1 000 lbs. at a point about four inches below ground level. The concrete broke, allowing the rods to be slowly pulled from the pole, with a gradually decreasing pressure to obtain further deflection. An interesting feature of this test was that the failure was gradual, and although the fault occurred in this case at the point of reinforcement and the concrete collar was broken, the pole was still strong enough to support the weight of the linemen and required the combined weight of three men to pull it to the ground.

FIG. 14—EXAMPLE OF ESPECIALLY DIFFICULT CASE OF REINFORCING

A notable application of this method of repair, in which its convenience as regards saving of both time and labor was an important feature, is illustrated in Fig. 14. This pole had become so impaired through butt rot that it could no longer be depended upon to carry its load. The ordinary procedure in such a case would have been to replace the pole by a new one, either in the same location or adjacent to it. In order to accomplish this the various wires, cables, and arc lamp mast arm supported by the old pole would have been transferred, and the cross-arms would have been taken off. Moreover, the final removal of the pole would be difficult when the wiring is so complicated as in this case.

This pole was not only repaired by reinforcement, but was also raised twelve inches in order to better meet the requirements at this point, the entire work being accomplished without exposing the linemen to the danger of coming in contact with any of the circuits and without in any way disturbing any of the feeder circuits, lighting lines and fixtures, telephone lines, or trolley span wire, all of which were dependent on this pole for support. By this method of repair a pole at least as substantial as the average to be found in service was obtained, with promise of no further attention being required for a long time.

The ordinary cost of replacing a defective pole by a new one, including the cost of the pole itself, haulage of the new pole to the point, labor of setting, transfer of wires and disposition of the old pole, has been shown by experience to be approximately $15.00. In extreme cases the cost may vary to even $50.00; for example, the cost of repair is increased where especially high poles are required or when the handling of main trunk lines near power stations is involved. This does not take into consideration loss of service and danger to linemen — items which cannot easily be estimated, but may be quite important.

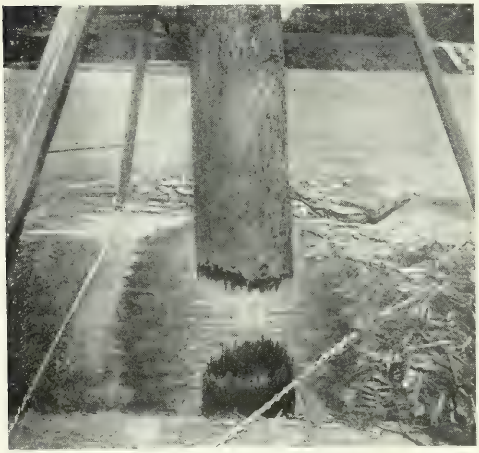


FIG. 15—METHOD OF HOLDING POLE BY MEANS OF TRIPOD, USING A PIKE POLE FOR EACH LEG AND CHAINS TO HOLD THESE IN POSITION

When the earth was dug away the pole was found to be so rotted that the wood was readily removed in chips. The pole had been held in place for some time by the overhead lines.

The expense of repairing poles by reinforcement with rods and cement is in strong contrast to the preceding estimates. For ordinary repairs, such as have been illustrated, the cost averages $3.50 per pole; it being increased, however, in case of isolated repairs and where more elaborate reinforcement is required, either for purpose of obtaining additional strength or as a sub-

stitute for guy wires. The cost even in such cases does not equal the minimum cost of renewal.

The inference drawn from the tests and other data obtained regarding this method of reinforcing poles by means of rods and concrete is that it gives reinforcement sufficiently strong to enable the pole to withstand a horizontal strain of not less than 1 000 lbs. applied 27 feet above ground, and that it is but a question of increasing the number of rods and the amount of concrete to meet any required strength. However, the results which have been outlined in the foregoing are considered to fully meet the re-

FIG. 16—REINFORCED POLES IN SERVICE

quirements of a practical reinforcement, giving a good factor of safety for all ordinary pole line construction, at a minimum cost and without the necessity of giving any attention to the overhead wires during the process of making the repairs.

Additional weight is given to these facts when it is considered that the deterioration of wooden poles is due principally to butt rot. Hence, a pole which has been in service until its strength is perhaps fifty percent of its original value, is not only restored to practically its original strength by application of this method of reinforcement, but by elimination of the possibility of rapid decay, its deterioration is much more gradual and its useful life is correspondingly increased.

ELECTRICAL APPLICATIONS IN MINING WORK

WITH SPECIAL REFERENCE TO MINING METHODS IN MEXICO

C. V. ALLEN

THE FACT that the use of electricity both increases the output of a mine and reduces the cost of production has been demonstrated by actual results obtained. Electric haulage has enabled one mining company to double the output of its mine and at the same time reduce the cost of haulage from eight cents to one cent per ton. The total yearly saving in this one item amounts to 30 percent of the sum invested in the electric power plant. The company also uses electricity for lighting and for the operation of machinery. At another mine the cost of haulage has been decreased from ten cents per ton with mules, to less than one cent per ton with electric locomotives. In a third, the substitution of motor drive for steam pumps at a total cost of $18 000, including generating plant, motors, etc., resulted in an annual saving of nearly $6 000, allowing for interest on investment and depreciation of the plant. The installation of an electric motor in a California mine, to take the place of steam power in driving a 100 horse-power air compressor, resulted in reducing the cost of operation from an average of $1 800 per month to $672.00.

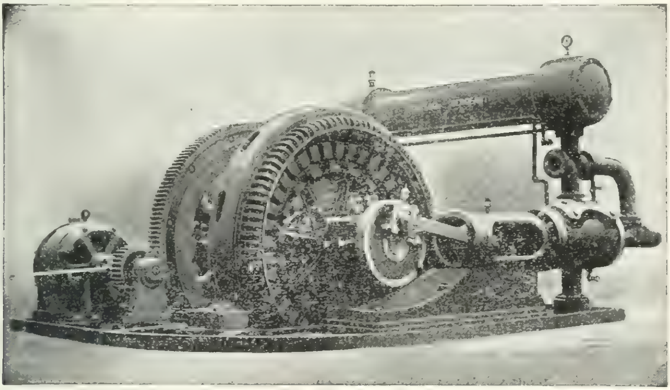
VENTILATION

In the mining of metalic ores, which is the only class of mining considered in this article, no trouble is encountered with the injurious and explosive gases which are common in coal mining. The larger mines in Mexico which are now being worked were started by the Spaniards a hundred or more years ago, before machinery for artificial ventilation was employed and, as a rule, have very good natural ventilation. A few small blowers or exhausters are employed to drive out the smoke after blasting, but no expensive ventilating plant is necessary. Even in the large mines of Las Dos Estrellas Company, where nearly 250 motors are employed, there are but two 65 horse-power motors driving ventilators and only four or five 10 horse-power blowers.

In many cases sufficient ventilation is obtained from the air

brought into the mine for motor-driven air compressors, for driving the air drills, tools, etc.

A motor-driven blower, when properly installed, requires little attention and runs continuously with only occasional cleaning and oiling, which is especially important since it is often desirable to locate ventilating fans at unfrequented points and at considerable distances from the power-house. A point which sometimes may be of considerable importance where there is a large number of motors located at widely separated points throughout a mine, is that they will start and stop with the starting and shutting down of the main generators in the power-house. If by reason of an accident or other cause the current supply is stopped, all the fans and other machinery in the mine may be started again promptly when the power is turned on,



MOTOR-DRIVEN AIR COMPRESSOR

Driven by 200 horse-power synchronous motor. The starting motor is shown at the left.

without visiting the different points where the apparatus is located.

PUMPING

The electric pump is certainly welcomed by mine operators as a most satisfactory substitute for the efficient steam and air pumping arrangements formerly employed. By its use the necessity of piping hot steam into a mine shaft, already warm and moist and sufficiently uncomfortable, is avoided. The cost of installing the wiring for the motors, as compared with the steam pipes, is much less and it occupies less space in the shaft compartment used for this purpose.

For mining work, both the centrifugal and plunger or piston types of pump may be used. There is considerable difference of opinion among operators as to which is the best to adopt, and in the case of equipping a new property, the operator is very frequently entirely at sea as to which to employ. The water in a mine is often not only quite acid but contains many chemicals in solution, as well as being very gritty; the latter being almost always the case, particularly when sinking is going on, at which time the water to be pumped is always stirred up and the grit contained therein has to be pumped out with the water. Where there is acid in the water handled by plunger pumps care should be taken that all parts which come in contact with the liquid are of bronze or brass.

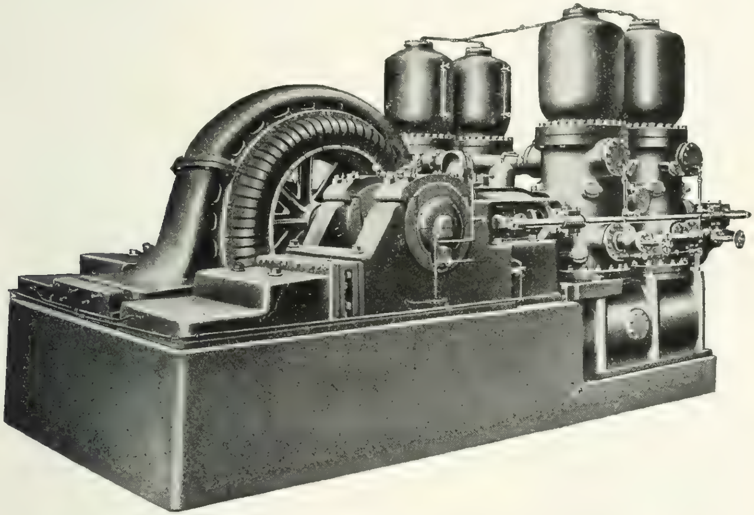
Types—The usual pumps employed in mines are station and sinking pumps. In Mexico numerous mines are fitted throughout with both centrifugal and plunger pumps for both classes of service. While it is true that a plunger pump is more efficient than a centrifugal pump for the corresponding service, the latter has the advantage of being simpler in construction. It is generally fitted with self-oiling bearings and consequently will stand more severe use and greater neglect, which is a distinct advantage in countries like Mexico where labor is not of an intelligent class.

In the case of a sinking pump, or any service where gritty water has to be handled, with a centrifugal pump the liquid comes in such direct contact with the runners and linings that it is a matter of but a short time before the parts show material signs of wear with resultant loss in efficiency. In order to reduce the weights of sinking pumps as much as possible, it is customary not to use them for heads above 350 feet; when a greater depth is reached a sump is built into which the sinking pump discharges and at which a station pump is located to force the water to the surface.

In opening a mine it is difficult and practically impossible to tell the amount of water that will be encountered. On this account a conservative operator will purchase with his original equipment a small sinking pump to have ready in case water is encountered, thus avoiding delay. Even when water has been found and the workings have progressed considerably, the flow of water may increase unexpectedly with any blast, and it is well for an operator to purchase a pump in excess of the capacity actually required at the time of ordering. In case this is a plunger pump it can be made to operate efficiently at reduced

capacity by the purchase, with the pump, of an extra set of gearing; with this means of reducing the speed, a pump with a capacity of, say, 250 gallons per minute, can be operated efficiently at 150 gallons per minute with a motor of sufficient capacity for the total output of the pump.

The plunger pump in this case has the further advantage that the water is handled without giving a direct wear on the plunger. One important operator, while admitting that a centrifugal pump wears out much quicker than a plunger pump, claims an economy, in the long run, in the operation of the former for



SYNCHRONOUS MOTOR DRIVING STATION PUMP

Installed at the Ward Shaft, Virginia City, Nevada. 800 horse-power, 2,000 volt motor; outside packed plunger pump, capacity 1,600 gallons per minute, head 1,550 feet.

certain classes of work, on account of the ease of repairing. He can cast his own runners and linings on the ground, whereas with a plunger pump the cost of repairing is much greater, as it requires the purchasing of parts from the manufacturer and an experienced man to put them in place. Another large operator who has several 50 horse-power, seven stage, electrical centrifugal sinking pumps has had one of these pumps wear out entirely in eight months' service on account of the gritty water.

It is pretty generally believed that, regardless of the mechanical conditions in service, a centrifugal pump is well placed where there is a large amount of water to be handled at low head; that is, say, from 60 to 75 feet, where a single stage pump

can be employed. Under these conditions a centrifugal pump is at its best efficiency; the plunger pump being more desirable with high heads. Nevertheless, there is one installation in Mexico comprising a sixteen stage centrifugal pump of German make pumping 150 gallons per minute against a 1 650 foot head. The pump is built in two parts to divide the thrust, with the motor in the middle.

Centrifugal sinking pumps have the advantage on account of the high speed at which they may be operated and the correponding reduction in weight and in the cost of motors. In short, on account of the few wearing parts, a practically fool-proof outfit is obtained.

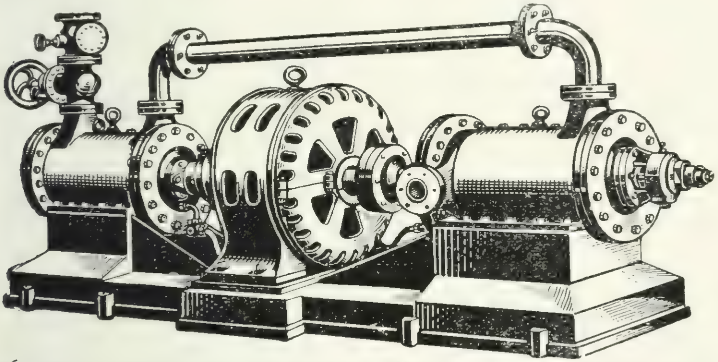
MOTOR-DRIVEN SEVEN STAGE CENTRIFUGAL SINKING PUMP

With station pumps, where it is desirable to arrange them with automatic float starters and to operate them nearly automatic and with as little attention as possible, a centrifugal outfit certainly appeals to the operator. A plunger pump outfit for this service practically requires a man in attendance night and day; whereas it is possible to start and stop a centrifugal pump from a distance by the switch controlling the motor. In the first case the cost of attendance will frequently more than counterbalance the difference in efficiency and repair of the pump. The plunger pump, by being driven through gearing, further has the objection of getting out of line more easily, and thus counteracting the better efficiency of the pump itself, while a centrifugal pump, driven by a motor through a flexible coupling, does not have this objection.

An old method of unwatering a mine, which obviates all the objections to both classes of pumps with pretty efficient results, is that of hoisting the water in small bull skins, these being filled with water and carried up pigeon ladders and out of the mine on the backs of men. This was the practice of the natives of Mexico over a hundred years ago, and some companies are still unwatering in this manner, except that now the skins are lifted full of water by means of electric hoists.

ORE HANDLING

Haulage—In gold and silver mines, electric locomotive haulage is almost never employed unless tunnel entrances to some of the levels are available. As a rule, the workings below ground are made as small as possible on account of the expense of working through solid rock, and push-cars or mules are employed to handle the ore cars below ground, as they occupy less space. The electric haulage comes into play at the surface or at the tunnel level, where the ore is dumped by the hoist and then hauled to the mill. The mill may be from one to two miles distant, depending on the most suitable site that is available. In locating a stamp mill precipitous ground is necessary in order to take advantage of gravity fall for the ore during the entire treatment



16 STAGE MOTOR-DRIVEN CENTRIFUGAL PUMP OF GERMAN MAKE USED IN MEXICO

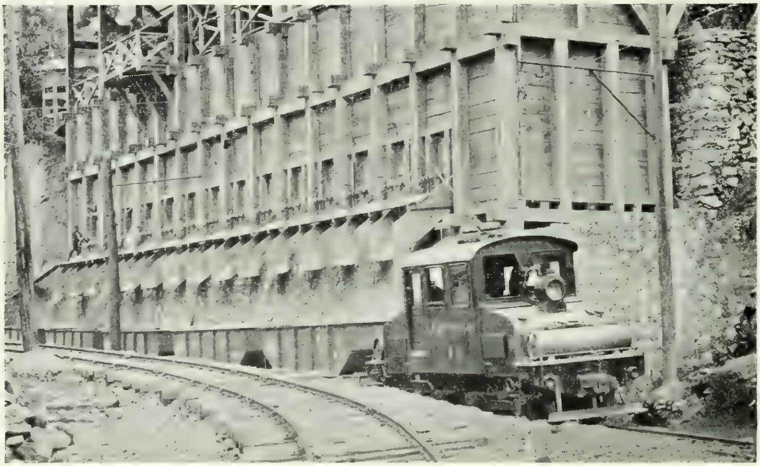
Capacity 150 gallons per minute against 1 650 feet head.

from crushers to zinc room. Tunnels into a mine of this kind are invariably constructed so that they will have a slight down grade in the direction in which the ore is hauled, the entrance to the tunnels usually being at a point above the mill site. By this arrangement a small electric locomotive can handle a large tonnage.

At one mine where they are using ten electric locomotives of different capacities from three to thirty tons, as many as forty-five loaded cars have been hauled out of the tunnel with a five-ton locomotive designed to handle eight cars. It might be well to add, however, that the forty-five car haul resulted in a burned out armature, at the expense of the motorman who accepted the load from the mine foreman. There are few pieces of apparatus about a mine which receive more abuse than an electric locomo-

tive, the usual practice being to increase the number of cars hauled, either loaded or on the return trip of empties, until the locomotive stalls at some curve or grade. This results in a large maintenance expense for armature coils, commutators, etc. The manager makes no complaint, however, as he realizes that he is using the locomotives at double or treble what they are designed for, and some prefer to operate in this way rather than buy larger locomotives.

In practically all installations of electric locomotives in Mexico a very marked saving has been experienced. In the case of one property, at the very first it showed a reduction in the cost of haulage per ton over the former method by push-cars, of 50

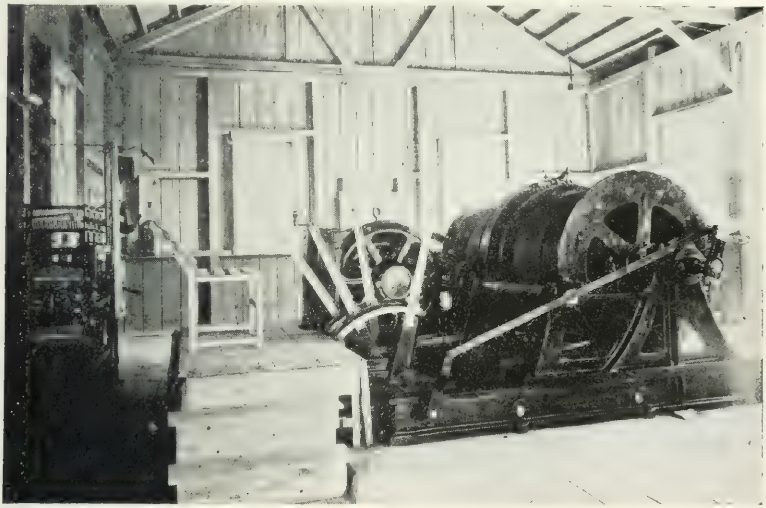


30 TON ELECTRIC LOCOMOTIVE HAULING ORE FROM ORE BINS
Compania Minera Las Dos Estrellas

percent, and to date the saving is from 60 to 72 percent. With another system the cost of haulage per ton over the former method of using mules, not taking into account the death rate of mules, was reduced from twenty-four cents per ton to about six cents per ton, making the cost of the electric haulage about one-quarter that of the former method. As with all cases of electric haulage, much greater convenience and more positive operation also results, as the ore bins are easier kept full and no time is lost at the stamps for want of sufficient ore. At large properties, haulage by push-cars requires a large gang of men. Holidays occasionally reduce the number of men available and the bins

then become empty, while they can easily be kept full by electric locomotives since only one man is required to handle twenty or more cars. At another property each locomotive and fourteen men replaced forty-five men previously employed, and they now handle a greater quantity of ore in a more regular and efficient manner.

Cable Ways—The mountainous country usually found about a mining property lends itself very well to a cable-way installation for handling the ore between mine and mill. There are many of these installations in Mexico, and in each gravity is taken advantage of, so that after the system is once installed it proves a



HOIST AT MILL NO. 1

Compania Minera Las Dos Estrellas. Driven by 100 horse-power induction motor.

very cheap method. A small motor is sufficient to start the system, the weight of ore in the buckets being enough to keep the system in operation after once in motion. This method requires very little power, a 10 or 15 horse-power motor being sufficient. Some of these cable-ways are from 3 000 to 6 000 feet or more in length.

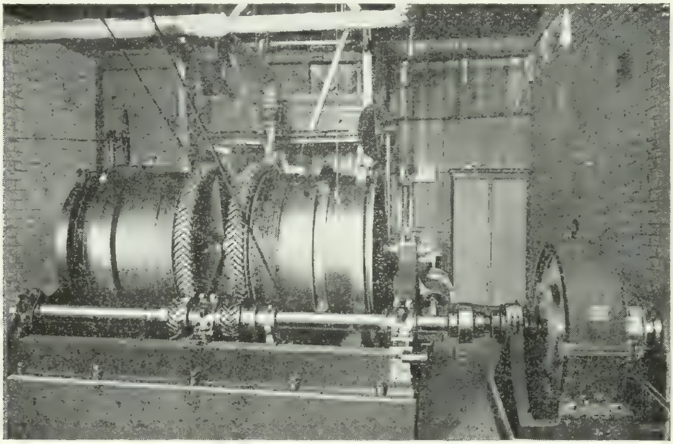
Hoisting—As most of the mining properties in Mexico using electricity are operated by alternating current, either from a local plant or, as is most generally the case with the largest consumers, power is purchased from a transmission company, there

are three general methods employed for hoisting electrically, viz.:

Straight induction motor,
Continuous running motor, and
Fly-wheel set.

There is a fourth method of hoisting which has been employed a little in the West, known as the counter-weight hoist.

As to which of these methods is best suited for a particular service depends largely upon the conditions at hand; one of the principal conditions being determined by the size of the hoist to be operated, and whether or not the operator purchases his power



HOISTING EQUIPMENT, NORTH SHAFT
El Oro Mining & Railway Company. Driven by 150 horse-power induction motor.

from a separate company or generates it himself; in the latter case the capacity of his hoist motors would undoubtedly be a large percent of that of the total plant, so that the peak load at acceleration would be a serious matter. If the operator purchases his current from a power company the method of charging for power would also determine largely the method of hoisting he would adopt. Another determining feature would be whether the power company makes a charge by actual kilowatts only, or by the kilowatt reading plus an additional heavy charge for any peaks over a certain time duration.

No remarks are necessary regarding the straight induction motor method of hoisting, except perhaps that care should be

taken in selecting a motor to take into account the service the hoist will have to meet; that is, whereas an intermittent rated motor may be suitable for a single drum hoist where the motor usually rests two-thirds of the time and is working one-third, with a double drum hoist the motor is working pretty continuously, and when hoisting water, which is often done, the motor practically has no rest, in which case a continuous rated motor should be used. The peak at acceleration, of course, is a maximum with this method, for which reason some power companies do not allow motors of over one hundred horse-power employing this method on their system. This method of hoisting calls for less apparatus, with correspondingly less first cost than with the other methods. There are two ways of partially reducing this objectionable accelerating peak:—one by use of a flat rope or reel hoist, the other by the use of a conical drum hoist.

The continuously running motor method of hoisting reduces somewhat the objectionable heavy starting current met with at time of acceleration in the previous method. In this case the motor runs continuously in one direction driving the hoist through a beveled pinion meshing into two beveled gears. These beveled gears run in opposite directions and to each of these gears a clutch is attached so that the hoist drum is operated in one direction or another, according to which clutch is clamped by the operator. These clutches are arranged interlocking so that one only can be clamped at the same time. By this method of using a continuously running motor there is the advantage of being able to utilize the fly-wheel capacity of the motor at the time of acceleration, producing a very material reduction in the peak of the hoisting curve. Although the motor is to operate continuously, at practically constant speed, outfits installed using this system should employ a variable speed motor with the usual controller and resistance for the reason that experience has thus far shown that frequently, due to trouble with the clutches, or whenever slow speed is desired, such as at a time when the shaft is being examined or repaired, this slow speed can be obtained by clamping the clutch firmly and running the hoist by means of the motor at reduced speed. Although this adds to the expense of the outfit it gives a much more flexible arrangement. Outfits of this type as large as 350 horse-power are being operated in Mexico.

The fly-wheel motor-generator set method of hoisting undoubtedly is the least troublesome. The entire hoisting cycle under this

method can practically be reduced to a steady load by employing a sufficiently large fly-wheel, but this system has the objection of greater first cost over the two previous methods mentioned. This objection, however, is counterbalanced by the reduced cost of operation where a charge for power is made on a peak basis and where the hoist is in service practically continuously and not idle for lengthy periods.*

A counterweight hoist consists of a single drum hoist with an auxiliary drum directly attached on which is wound a rope supporting a counterweight which moves up and down in the shaft. This auxiliary drum is made a little smaller than the main drum in order to keep the counterweight clear of the top and bottom of the shaft. By this method the peak at starting is reduced and a fairly steady amount of power is drawn from the transmission line, as the weight has to be lifted while the empty cage is returning for another load. It has been claimed for this system that about 25 percent greater amount of ore can be lifted with the same size of motor than can be accomplished with a double drum hoist in the same time, a larger amount being hoisted each time than would be possible without the counterweight. One of the principal advantages of this system seems to be the reduction in the amount of shaft compartments necessary. A two compartment shaft instead of a three compartment will answer with this method; one for the cage, the other for the piping, wiring, ladders, etc., and also to carry the counterweight, which is made up of long, slim, iron washers or weights, which are slipped over the cable and any desired number used, according to the particular hoisting conditions.

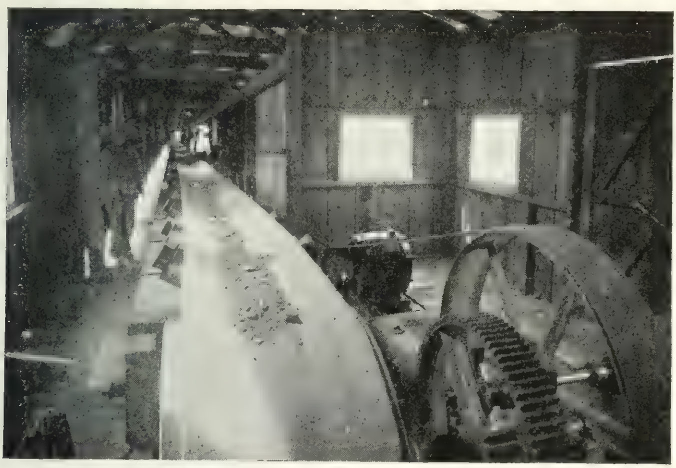
The first cost of the various systems is practically inversely proportional to their relative advantages. Invariably, where a large hoisting outfit is to be purchased all these conditions have to be studied carefully in conjunction with the power company in order to determine the best method to employ.

CRUSHERS AND ROLLS

The capacities of motors necessary for this class of machines vary, depending on the size of fly-wheels with which they are furnished by the manufacturer, and on the hardness and size of the pieces of ore fed to them, also whether or not a

*This method of hoisting was described in the JOURNAL for June, 1909, p. 327.

continuous stream is fed in from a hopper or shoveled in by hand to the jaws. It is rare that too small a motor is installed for this service, but it is very common to find that the motors are not well placed to protect them from the excessive dust. If the motors are located above, the dust rises to them or is carried up by the belts, and even though the motors are thoroughly boxed in, the opening for the belt is sufficient to carry a great deal of dust to the motor. The nature of this dust is such as to eat out the bearings in a very short time. A good and effective way to protect the motor is to employ an extended shaft with outboard bearing, placing the motor in a closed compart-



ELECTRICALLY-DRIVEN ORE BELT CONVEYOR CARRYING ORE FROM CRUSHERS
El Oro Mining & Railway Company.

ment with its shaft only extending through a wall or partition, thus leaving only the pulley and third bearing exposed to the dirt. One large company has now been operating a year and a half without a single burnout, or the use of any spare parts whatever and they attribute their success to their having laid out their plant carefully, locating their motors in protected places and keeping them clean after they were in service by the use of an air-blast from the compressed air pipes.

The crusher motor is often called upon not only to drive rolls but an automatic sampler and elevator for elevating the ore to these machines. The crusher is invariably located above the mill so that either a gravity tramway or belt conveyor carries the

crushed ore into the mill over the ore bins above the stamps, this ore being distributed by automatic distributors, which keeps a uniform level in the bins.

The jaw type of crusher is easier on a motor than the gyratory type, for the reason that very heavy fly-wheels are used in the jaw type, whereas the gyratory type has practically no momentum to relieve the shocks from the motor. Furthermore, in shutting down a jaw crusher the momentum of the fly-wheel is usually sufficient to clear the crusher so that when ready to start again it is without load, which is not the case with the gyratory type.

STAMPS

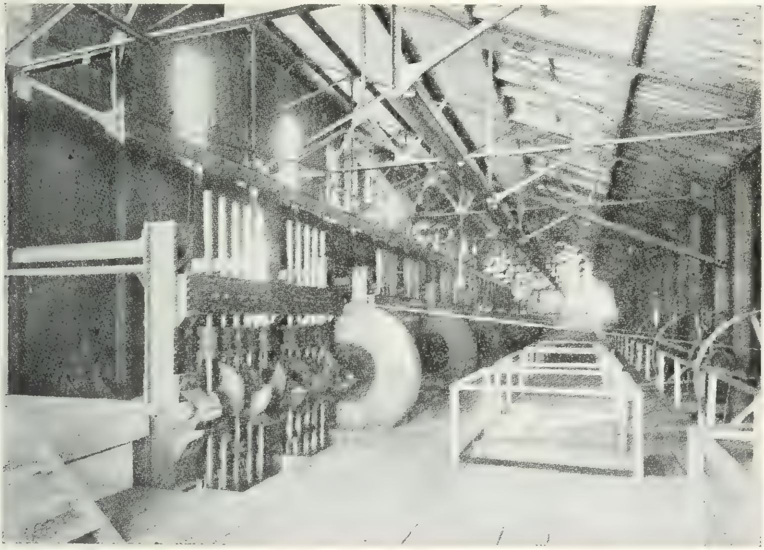
Where a stamp mill has been operated by steam engines and later converted to electric drive, as was the case with the El Oro Mining & Railway Company, which has two 100 stamp mills, there has been some uncertainty as to whether electric power would be supplied without interruption since the transmission of power was from quite a distance. A motor of sufficient capacity to drive each entire mill, instead of individually driven sections, was therefore installed. By this arrangement, in case of failure of power, the former steam engine could still be brought into service to prevent a shut-down of any length of time. However, the electric power has proven so reliable that new mills recently built in this camp have been fitted up entirely with electric motors without a particle of steam being applied.

The stamp mills in Mexico run from ten to 130 stamps per mill; the units ranging from ten to forty stamps per motor. It is not well to run less than ten stamps per motor for the reason that the thrust on the cam shaft of one set of five stamps is counteracted by an opposite thrust from the adjacent set of five stamps. Operators differ as to the best division of drives. The manager of one large property has decided that with a new mill, which he is about to build, he will divide all his drives into ten stamps each.

Every possible way to avoid the double reduction drive from motor to the cam shaft has been tried in stamp mill work, but this seems impossible to accomplish. The usual motor speed is 690 or 720 revolutions per minute, depending on the frequency, and the cam shaft must make 50 to 52 revolutions per minute, in order to give 100 to 104 drops to the stamps per minute, there being two cam engagements per revolution. As the cam shafts are driven from the countershaft by short belt drives, generally employing an

idler pulley, in groups of ten stamps, any group may be shut down without stopping the motor, by slacking away on the idler.

The arrangement of a stamp mill is such that a good, protected location for the motor to give good distances between centers is not easily found. It is impracticable to locate the motor in front of the stamps on the floor level, as the belting interferes with the passageway necessary in front of the stamps. On this account, therefore, in the construction of a new mill one of the best places for the motors is a special compartment built back under the ore bins. This should be large enough for the motor control panels and for a man to get around the motors to give them proper care.



CAM SHAFT FLOOR OF A 100 STAMP MILL DRIVEN BY ELECTRIC MOTORS
At the Gold Prince mill. A separate motor is provided for each 10 stamps.

The Homestake Company in South Dakota, where 1 000 stamps are operated in five different mills, have partially electrified their installation and are driving 360 of their stamps in groups of ten, each with 25 horse-power, back-geared motors. These are 900 pound stamps, with nine inch drop and 94 drops per minute. By the use of back-geared motors there is but one belt drive connecting directly to the cam shaft, which simplifies the transmission considerably by cutting out the usual many belts and long countershafting. In this case the motors are located in front of the stamps on elevated platforms above the amalgamating tables. The Mait-

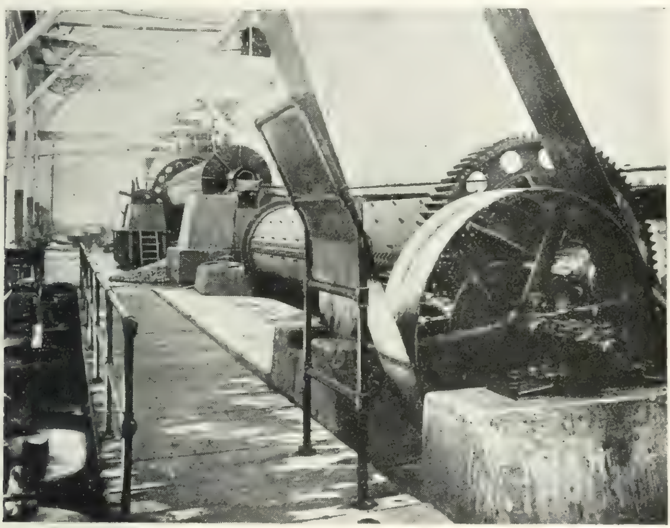
land mill, located near the Homestake, uses the same method of driving its 40 stamp mill with very good results.

Cyaniding is comparatively a new process in Mexico and there has been very rapid development and consequently many changes in the method of the treatment of ores in the last two or three years. Formerly the product from the stamps was passed over copper amalgamating plates before passing to the cyanide plant for treatment. Very recently a number of plants have begun to use a coarser mesh at the stamp batteries and depend more and more upon the tube milling to obtain the finer grinding, turning everything into slimes. This results in the stamps being able to crush a much greater tonnage, and with some of the larger companies the amalgamating plates have been taken out entirely, so that the product from the stamps passes directly to the tube mills after being classified, without any attempt at amalgamation.

TUBE MILLS

The whole process of treatment in a gold and silver mill is to reduce the ore to the fineness of flour in order that the cyanide can the more readily dissolve out the gold and silver by coming in closer contact with them. After the process of grinding, the material is again classified in order to separate the coarse from the fine; the coarse being returned for regrinding. The action of the cyanide begins even at the stamps in most cases. Instead of the liquid at the stamps being water, as formerly, a number are now stamping in solution of cyanide, so that the action of the cyanide on the ore is going on from the time the ore arrives at the stamps. It is the duty of the tube mills to grind still finer the products delivered from the stamps and these mills vary greatly as to size and make. They are driven by individual motors, or sometimes two or three mills are driven from one motor through a common line shaft with friction clutches employed to shut down any mill which may have to be relined or refilled. The weak point about a mill is its lining, which wears rapidly. All kinds of experiments have been tried to determine the most durable lining and, to date, the problem seems to have received its best solution in an invention by Mr. Brown, of the El Oro Mining & Railway Company, who invented what is called the "El Oro Tube Mill Lining." The white iron and silex linings are replaced by a certain form of steel casting bolted to the inside of the tube mill. Norway pebbles are introduced into the mill, the mill charged and in a short time the pebbles become tightly hammered into the grooves of the castings, so that they in reality

form the actual lining and the grinding continues between the loose pebbles within the mill and the pebble lining. It has recently been found that where a hard quartz ore is available, which also contains values, this may be fed into the mill in place of pebbles, and while assisting in grinding the sands they are thus pulverized themselves and the values within them liberated. The pebbles from Norway are extremely expensive when delivered on the ground, particularly so if the mill is located inland and they have to be transported on muleback, so that the economy by using the hard ore containing values is quite



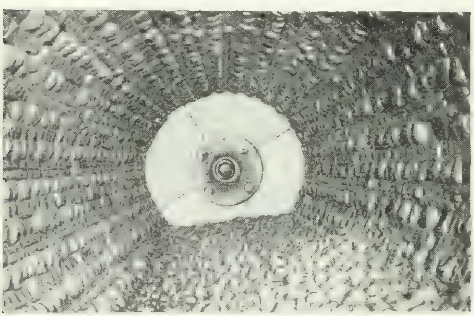
TUBE MILL NO. 2, BELT DRIVEN BY ELECTRIC MOTORS
Compania Minera Las Dos Estrellas.

appreciable. It was formerly the practice to fill the tube mill with a certain amount of pebbles and run it until it was necessary to shut down and add more pebbles. The present practice, which is rendered possible by a new method of screw feed, is to throw in the hard ore at one end gradually as the wear takes place, so that a shut down on this account is not necessary.

As with the stamp mill drives, the size of the motor used in driving the different tube mills is determined largely by the conservatism of the operator. The tube mill requires about twice as much power to start as to run after starting. Tube mill motors should be provided with high resistance end rings

on the secondaries for giving a high starting torque. One property using fifteen mills, all of which, with the exception of two, are Krupp No. 5, have provided 75 horse-power motors which consume from thirty-seven to thirty-nine kilowatts each continuously. The general drive is by belt from the motor with double reduction, the second reduction being a gearing arrangement on the mill itself and supplied by the mill manufacturer. The motor speed is generally 580 r.p.m., for a belted arrangement. Another less common practice is to couple the motor to the geared countershaft of the mill, in which case the motor makes 240 revolutions. Another company is running ten of these same size tube mills with 60 horse-power motors.

All of these latter mills, like the part of those above mentioned, are used to regrind tailings, which formerly, under the previous method of treatment, were abandoned as worthless, and which, by this new treatment of tube milling and the cheaper electric power, can be treated with profit, thus extracting values still contained in the particles of sand which the cyanide failed to reach in the first treatment. These tailings, after being passed through the tube mills, are returned for treatment in the cyanide plant.



INTERIOR VIEW OF TUBE MILL
Showing El Oro lining.

The first cost of a large motor driving two or three mills through clutches is without doubt less than for individual drive. However, one of the mills is pretty sure to be shut down for attention, so that the motor is but one-half or one-third loaded, whereas, with individual installations, motor and mill are shut down together. The individual arrangement has, however, the disadvantage of requiring a larger motor for starting conditions than is necessary after starting. In cases where clutches are not installed between mill and motor, it is a good plan when starting to switch on the motor enough to give the mill an impulse, bring the starter back to the "off position" and then give it another similar impulse at the time when the mill is ready to make its next forward move-

ment, repeating this two or three times before throwing the motor on to the main line. This method of oscillating the mill is easier on the motor and also on the supply circuit and will start up a large mill with much less current than if the motor is thrown on the line direct with the mill at rest.

The conditions of operating Bryan, Chilean and Huntington mills are so similar to those of a tube mill, on account of the large mass necessary to start, that the above remarks apply pretty generally to this class of machines.

CONCENTRATING TABLES

Concentrating tables generally require from a half to one horse-power each at the table pulley, and as they are slow-speed machines, a number of them are generally belted to a common line shaft, driven by a motor. As a rule 1 120 r.p.m. motors are installed for this service, the capacity of motor depending upon the number of tables driven from the shafting and the arrangement of tables and shafting employed.

The Utah Copper Company and the Boston Consolidated Copper Company, at Garfield, Utah, have large quantities of concentraters in use; the drive with the latter company comprising a 30 horse-power motor for 52 Johnson tables and 40 horse-power motor for 65 Wilfley tables.

SAND PUMPS

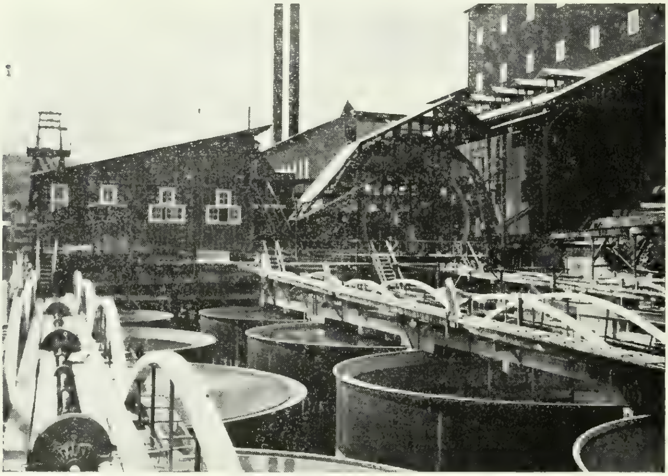
There is a great variety of centrifugal type sand pumps on the market all of which, naturally, wear out very quickly. A less expensive way to handle the sands about a mill, but of rather expensive construction, is by means of what is called a tailings wheel, which is a large wooden wheel some thirty feet in diameter, with buckets built in on the rim which dip into the sands and lift them to a trough above. One of these wheels, driven by a ten or 15 horse-power motor, will handle a large amount of sands with practically no wear.

CYANIDE PLANT

The process of cyaniding for silver is comparatively new; different operators employ different methods, all of which in general are conducted along similar lines, differing only as to details. The character of the ore influences the methods adopted, the strength of the cyanide solution to be used to give the best results, the method of agitation employed, the type of filters installed, etc. Where but a short time ago quite an elaborate system of belt con-

veyors, mechanical excavators, sand distributors, for the treatment of sands apart from slimes, was considered necessary by some of the larger companies for a certain class of ore, it has since been found that better results can be obtained by converting all the product from the stamps into slimes, thus rendering useless the former machinery used for handling the sands. In fact, some of the mechanical excavators have been converted into mechanical agitators.

The whole principle of the cyanide plant is to thoroughly mix the cyanide solution and keep it in circulation so that the cyanide will come in contact with the particles of gold and silver contained



VIEW OF THE CYANIDE PLANT OF EL ORO MINING & RAILWAY COMPANY

Tailing wheel, for handling sands, in the rear. Slime tanks in the foreground. The agitators are operated by means of a shaft extending over each row of tanks, (driven by a 40 horse-power motor.) The vertical shafts of the agitators are driven from the main driving shaft by means of bevel gears and clutches.

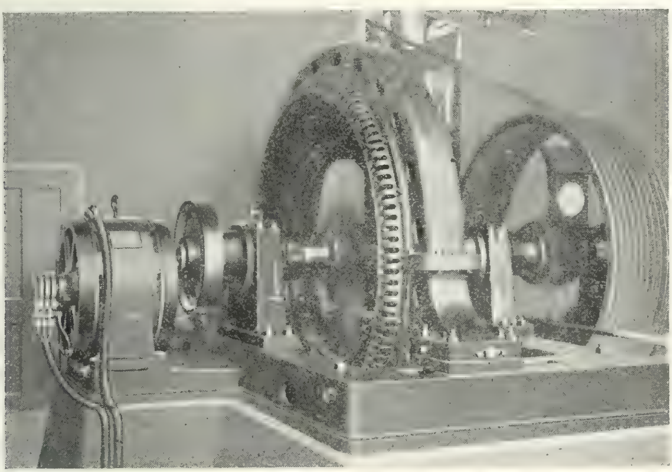
in the slimes and dissolve them. These slimes are agitated mechanically, by compressed air and by pumping; very often all three methods being employed in the same plant.

AGITATORS

Mechanical—These consist of a series of paddles made to revolve in a large sheet-iron tank; these tanks are sometimes made of wood or masonry, various methods being employed to prevent the solution from following the paddles around in their movement, in order to obtain as thorough mixing as possible.

In one plant the slime tanks are arranged with motors located in the center of a group of tanks they are to agitate, on a bridge above them. This gives a shorter line shaft which can be kept in better alignment. With this installation 30 horse-power motors are used, about half of the tanks being agitated at one time.

Air—For air agitation compressed air at about thirty pounds pressure is used. The air is piped around the slime tanks and a portable air pipe arrangement is inserted into the liquid and is moved around by hand from above. This thoroughly stirs up the bottom of the solution and at the same time aerates it, which is a necessary part of the treatment.



350 HORSE-POWER SYNCHRONOUS MOTOR DRIVING MAIN POWER SHAFT
El Oro Mining & Railway Company.

Pump—Pump agitation consists in pumping the solution in the tanks out at the bottom and in at the top, so that the lift is about twenty to thirty feet at the most and, to date, centrifugal pumps have always been used on account of the excessive wear of the parts and ease of repairing these pumps. A triplex pump has been designed to handle this work which, in order to obviate the wear on the packing by the grit, introduces a special water packing which consists of an arrangement by means of which a stream of water is forced against the plunger at each stroke, thus washing it off before it goes through the packing to prevent its wear. These pumps are of slow speed—not over forty revolutions per minute—and will

consequently call for a double reduction gearing when driven by a motor. On account of the slow speed of these pumps a larger pump will have to be supplied for this service than is usual for handling water or other solutions. Few of these have yet been put into practical use on other than thin slimes. If this pump is successful it will doubtless be very acceptable on account of its better efficiency. They are fitted with iron ball valves; in fact, all pumps used in handling any cyanide solution must have all parts coming in contact with the liquid of iron.

To handle slimes by centrifugal pumps the pipe must be of good size and the speed of the pump high to prevent any sticking or stoppage, as the solution has the appearance of very muddy water and is inclined to choke the pipes. The Butters pump, of which large numbers are used in Mexico, was particularly designed for this class of work and is so constructed that the runner and lining can be removed by unscrewing but five bolts which hold as many clamps. A fifteen to twenty horse-power motor will handle the usual conditions of service driving a six-inch pump, which is the popular size.

It is always desirable to place these pumping outfits as close as possible to the tanks they are to agitate to avoid piping and pipe losses. After a sufficient amount of agitation the solution is allowed to settle and the clear liquid is decanted. The charged solution finally arrives at the zinc room quite clear with the values contained therein, and is made to pass through a series of zinc boxes made of wood or steel which are filled with zinc shavings. The cyanide solution passing through these shavings from bottom to top consecutively dissolves the zinc, forming an oxide precipitate which is put through a filter press to extract the liquid, leaving a powder resembling a very black, thick mud; this is briquetted, heated in crucibles, the zinc vapor passing off, leaving the bullion which is molded into bars and shipped.

The only power required in a zinc room is a small five, ten or fifteen horse-power motor which drives the filter press pump to maintain a pressure on the solution in the press. A triplex pump is usually employed.

As cyanide is very expensive, as little as will give the best results is used, and as much as possible is recovered at the end of the process. One of the principal uses for power in the cyanide treatment is for driving the solution pumps, which return the

solution, after it has served, to the upper level of the plant to be used again.

Slime filter presses have recently come into use and there are several different makes on the market, some operating on pressure and others on a vacuum principle. These require little power, merely a small motor of about 20 horse-power to drive a vacuum pump. In the case of the pressure filter presses the pressure can be obtained by gravity and a pump used to return the water recovered by the process. With a Moore or Butters filter, where large leaves have to be handled, two small motors are used on the crane; one for lifting the leaves out of the press and the other for moving the crane forward and backward. The object of these filters is to recover as much of the water or solution as possible, not only to save the cyanide but also the water, as with the majority of mills water is scarce and very often large dams have to be built to store up sufficient water for the milling and cyaniding work.

In the above descriptions it has been the aim to refer to the subjects in the order of the process of treatment, as nearly as possible. As no two installations are exactly alike, there must be changes in the method of making electrical applications and this is where the local engineer's ingenuity comes into play, in devising special methods not found in any catalogue or hand-book. On the whole, it is safe to say that there is no industry more easily adapted for individual motor drive than that of mining and milling, the strongest supporters of motor drive being those who are using electrical power.

LINE SHAFT DRIVE AND INDIVIDUAL MOTOR DRIVE IN MACHINE SHOPS

A. G. POPCKE

POWER for the operation of machine tools may be furnished either by individual motors or from a line shaft. In laying out an installation of machine tools, the relative merits of the different methods of drive should be carefully considered. The first cost of drive from a line shaft is usually less than by individual motors. In a great many cases line shaft drive has been installed without giving due consideration either to the advantages or the savings which can be effected by individual motor drive.

The writer has at hand a number of experimental tests from which the following analyses have been obtained. Formerly practically all shops were driven from long line shafts and the speed regulation was very poor. A break-down anywhere in the shop would then shut down the whole system. So simple a thing as a belt leaving its pulley was likely to cause a cessation of work for a considerable length of time. More recently the steam engine has been replaced in many cases by one large motor, thus securing more uniformity in speed regulation. Then came the division of tools into groups with an individual motor for each group. By this method even better speed regulation is obtained and there are fewer general delays.

For most kinds of service, however, the advantage of making each tool independent of others has become evident to close observers. It is found that with individual motors, higher speeds and deeper cuts are possible. The water-hardened steel cutting tools formerly used would not permit this, nor was the structure of the old line-shaft-driven tools strong enough to stand the additional stresses due to heavier cuts. High-speed steel came to meet the first need, and stronger construction soon brought the machine tools in line. To the advent of the electric motor, then, can be ascribed the commercial development of high-speed steel and many improvements in machine tool construction.

Increased economy in the operation of manufacturing machinery can be effected in two ways:—

1—By reducing the power required to operate the machinery.

2—By reducing the time required for a given operation, or, in other words, increasing the output in a given time.

When confronted with the problem of deciding between the continued use of an existing line shaft or individual motor drive, or when deciding between the two methods for a new installation, the problem should be impartially considered in all its phases, somewhat as outlined in Table I. This table includes every important item to be considered, except one, and in every case the advantage is with the motor.

Comparative first cost is possibly the first consideration to enter the mind of most men, and this is the one consideration purposely omitted from Table I. That this consideration is of relatively minor importance, is evident when the saving in power consumption and in time made possible by the use of individual motors is considered.*

ECONOMY IN POWER CONSUMPTION

In order to determine the power required to drive line shafting and to obtain data for making accurate estimates, tests have been made by the aid of a graphic recording meter on motor-driven line shafts. The fact that these shafts were motor-driven gave them some advantage over engine-driven shafts, and made accurate measurements possible, otherwise the method of driving the line shaft need not be considered here. In each case the line shaft was belted to short counter-shafts from which the machine tools were driven. In the following discussion all references to the power required to drive the line shaft are understood to include the power requirements of the counter-shafts and connecting belting.

Test No. 1—This test was made on a lightly loaded line shaft driving three machine tools, the conditions being as follows:—

Length of main shaft, 115 feet.
Diameter of main shaft, 3 inches.
Self-oiling bearings every eight feet; dimensions 3 in.x12 in.
Couplings every 24 feet.
Driving motor, 40 hp, 720 r.p.m.

*See article by the author in the JOURNAL for December, 1909.

Machine tools—
One 14 ft. boring mill; maximum power requirement 3 kw
One 48 in.x10 ft. planer; maximum power requirement 2 kw
One 10 ft.x20 ft. planer; maximum power requirement 3 kw
Maximum power requirement with all tools working ——
at maximum output............................8 kw

The test showed that 4.5 kw input to the motor was required to drive the line shaft with no machines operating. Tests lasting over several hours showed that the machines while operating under existing shop conditions required an additional

TABLE I—COMPARISON OF LINE SHAFT DRIVE AND INDIVIDUAL MOTOR DRIVE

Item	Line Shaft Drive	Individual Motor Drive	Advantage of Individual Motor
1—Power consumption	Constant friction. Loss in shafts, belts and motor. Power for cutting	Friction loss (motor and tool only) and useful power only while working	Less power required
2—Speed control	No. speeds = No. cone pulleysxNo. gear ratios	No. speeds = No. controller pointsxNo. gear ratios	More speeds possible. Time saved in making speed adjustments
3—Reversing	Clutch and crossed belt	Reversible controller	Time saved in reversing
4—Adjusting tool and work	Stopping at any definite point very difficult	Can be started in either direction and stopped promptly at any point	Time saved in setting up and lining up a job
5—Speed adjustment	Large speed increments between pulley steps	Small speed increments between controller steps	Time saved in obtaining proper cutting speed
6—Size of cut	Limited by slipping belt Large belts hard to shift	Limited by strength of tool and size of motor	Time saved by taking heavier cuts
7—Time to complete a job			Much less time required as indicated for previous items
8—Liability to accidents	Slipping or breaking belts. Injury to machine tool, cutting tool or prime mover	Injury to machine tool, cutting tool or motor	Much less liability to accidents
9—Checking economy of operations	Close supervision required. Very difficult to locate causes of delay	Accurate tests possible by means of graphic records	Causes of delay and the remedies easily located without personal supervision
10–Flexibility of location	Location determined by shafting, and changes are difficult.	Location determined by sequence of operations. Changes readily made	Greater convenience in handling work and increased economy of operation. More compact arrangement possible

average input of only about 1.5 kw; that is, the total motor input was approximately 6 kw. Of this amount the line shaft required 75 percent and the machine tools only 25 percent, including their friction and power requirements.

Assuming the cost of power at two cents per kilowatt-hour, and that a working year contains 2 808 hours (54 hours per week), the cost of power for the foregoing installation would be $6 \times 2\,808 \times \$0.02 = \$336.96$ per annum, of which 75 percent, or $252.72, is chargeable to the line shaft. This assumption of power cost is low for many installations, especially for small, isolated plants.

While making the foregoing tests the machines were not all operating at full capacity. Assuming the best practical average operating conditions to be full capacity of each tool one-half of the time or one-half capacity full time, the machines would require 4 kw. The total average input to the motor would then be 8.5 kw, of which the line shaft would absorb 53 percent and the machine tools 47 percent.

The power cost at two cents per kilowatt-hour under the foregoing assumptions would then be $8.5 \times 2\,808 \times \$0.02 = \$477.36$ per annum, of which 53 percent, or $252.72, is chargeable to the line shaft.

Test No. 2—This test was made on a moderately loaded line shaft driving five machine tools. The details of the shaft construction were the same as in Test No. 1, and the other conditions were as follows:—

Driving motor 30 hp, 720 r.p.m.
Machine tools—

One 14 ft. vertical boring mill; maximum power requirement	3 kw
One 5 ft. radial drill; maximum power requirement	2 kw
One 7 ft. radial drill; maximum power requirement	2 kw
Two No. 8 Niles horizontal boring, drilling and milling machines; maximum power requirement, each	3 kw
Maximum power requirement with all tools working at maximum capacity	13 kw

The input to the motor, when driving the line shaft alone, was 3.5 kw. Tests of several hours' duration showed an average of 2.1 kw additional to drive the tools under practical operating conditions. That is, the total average motor input was 5.6 kw, of which the line shafting absorbed 63 percent and the machines only 37 percent.

The annual cost of power, at $0.02 per kilowatt-hour, would

be 5.6×2 808×$0.02=$314.50, of which 63 percent, or $196.56, is chargeable to line shafting and the remainder, $117.94, to the tools.

The maximum input to the motor observed during the test was 6.6 kw; but assuming, as before, a maximum average of one-half full capacity, the machines would require 6.5 kw, making a total average input of 10 kw, of which the line shaft would require 35 percent and the tools 65 percent. The power cost, at $0.02 per kilowatt-hour, would then be 10×2 808×0.02=$561.60 per annum; 35 percent, or $196.56, being chargeable to the line shaft, and 65 percent, or $365.04, to the tools.

Test No. 3—This test was made on a heavily loaded line shaft driving 12 machine tools. The length of the line shaft was 300 feet, all other dimensions of the shaft, bearings and couplings being the same as in test No. 1. The driving motor was 40 hp, 720 r.p.m., and the tools consisted of three planers, five boring mills, three radial drills, one slotter and one milling machine.

The input to the motor for the shaft alone was 6.3 kw, and the average additional input for the machine tools was 8.0 kw, making a total average input of 14.3 kw. Of this total the shafting absorbed very nearly 44 percent and the tools the remainder, or 56 percent. The annual cost of power, with the former assumptions, would be 14.3×2 808×0.02=$803.09, of which 44 percent, or $353.36, is chargeable to the shafting.

If all the tools driven from this line shaft were working simultaneously at full capacity they would require a motor input of 42 kw. The maximum input to the motor observed during the test was 19.4 kw. Assuming, however, maximum practical average operating conditions to be half capacity full time, the machines would require 21 kw, making a total input of 27.3 kw, 23 percent being chargeable to the line shaft. The power cost at $0.02 per kilowatt-hour would then be 27.3×2 808 ×0.02=$1 533.17 per annum, of which $353.36 is chargeable to the line shaft.

ECONOMY IN TIME

The relative time economy of motor drive and shaft drive is best illustrated by comparing the two methods for a given installation. The overhead charges, consisting of interest, in-

surance, taxes, repairs to plant, salaries, etc., are practically the same for either method of driving.*

For purposes of comparison, the cost of equipping the tools referred to in Test No. 2 with individual motors will be considered, and the saving to be effected thereby estimated. The data

TABLE II—MACHINE TOOLS AND OPERATING COSTS OF TEST NO. 2

Machine Tool	Operating Costs		Individual motor	
	*Overhead	Wages	HP	Cost Including Controller
14 ft. Vertical Boring Mill....	$1 50	$0 35	10	$ 370
5 ft. Radial Drill............	50	0 30	5	255
7 ft. Radial Drill............	1 20	0 30	7.5	290
No. 8 Horizontal Boring Mill.	3 00	0 35	5	200
No. 8 Horizontal Boring Mill.	3 00	0 35	5	200
Total Costs..........	$9 20	$1.65		$1 315

*See the JOURNAL for December, 1909, p. 757.

used for making the comparison are based either on actual tests or assumptions warranted by experience.

The overhead cost and wages per year of 2 808 hours (54 hours per week), for either line shaft or motor drive, from Table II, are:—

Overhead . . . . $2\,808 \times 9.20 = \$25\,833.60$
Wages . . . . $2\,808 \times 1.65 = \quad 4\,633.20$

Total $30 466.80

The cost of a large motor and line shaft drive for the foregoing installation is approximately $900. The cost of the individual motors is $1 315, as indicated in Table II. Assuming that the cost of attachments, changes in tools to fit them for motor drive, wiring, etc., is the same as the cost of line shaft drive, $900, the total cost of the individual motor installation is $1 315+$900=$2 215.00.

The cost of power for line shaft drive, as determined from Test No. 2, is $314.50 per year, with power at two cents per kilo-

*As indicated in the author's article in the December, 1909, issue of the JOURNAL.

watt-hour, of which $117.94 is chargeable to the tools. In some cases the installation of individual motors has resulted in more than 20 percent increased output, but assuming a conservative estimate, ten percent, the power cost can safely be placed at $130 per year. Calculating interest on the cost of the machine tool at six percent and depreciation at ten percent, the operating costs can be compared as follows:

	Line Shaft	Indiv. Motors
Overhead and wages	$30 466.80	$30 466.80
Interest and Depreciation @ 16% on costs of installation, $900 and $2 215, respectively	144.00	354.40
Power	314.50	130.00
Total	$30 925.30	$30 951.20

This comparison shows a balance in operating costs of $30 951.20—$30 925.30=$25.90, favoring the line shaft drive. Experience has shown, however, that tools equipped with individual motors will turn out at least ten percent more finished product than they will when line-shaft-driven. Assuming that the earnings of the shaft-driven tools are just equivalent to their operating costs, an increase of ten percent in output makes 0.10 ×$30 925.30=$3 092.53 increased earnings per year abtainable by the use of individual motors with scarcely any increase in expense, leaving a net annual profit of approximately $3 092.53 —$25.90=$3 066.63, favoring the motor drive.

With the assumed maximum practical operating conditions given under Test No. 2, the power cost for line shaft drive is $561.60, $365.04 being chargeable to the tools. Assuming ten percent increased output with individual motor drive, the cost of power would be about $400. The comparison of line shaft drive and individual motor drive would then be as follows:—

	Line Shaft	Indiv. Motors
Overhead and wages	$30 466.80	$30 466.80
Interest and depreciation	144.00	354.40
Power	561.60	400.00
Total	$31 172.40	$31 221.20

This assumption leaves a balance of $48.80 favoring line shaft drive, provided the increased output with motors be not considered. When allowance is made for ten percent increased output, the comparison shows $3 117.24—$48.80=$3 068.44 per year favoring individual motor drive.

The foregoing analyses show that the only consideration favoring line shaft drive—namely, lower first cost—is much more than overbalanced by the increased production possible with motor drive; also, that the cost of power, though in favor of motor drive, plays a very small part in the determination of operating expenses in a machine shop. It is to be noted also that the higher the cost of power the more favorable the proposition becomes to individual motor drive.

The foregoing shows that the question of whether or not to use individual motor drive on any particular case is a financial one and must be properly analyzed. The best way for a shop manager to solve this problem is to be guided by the following question:—What investment shall I make and how shall I equip my shop so as to obtain the greatest income upon the investment? Individual drive means an increase in investment, but in nearly all cases a much greater percentage income will be reaped than if line shaft drive were employed. The above discussion shows in a general way how to determine the best arrangement for driving a shop in any given case.

THE TRAINING OF NON-TECHNICAL MEN*

C. R. DOOLEY†

IN electrical engineering the proper and efficient arrangement of iron, copper and insulation, is only a part of the problem. The proper and efficient arrangement of brain and muscle providing for higher individual efficiency of all classes of men who are to carry on the business of the future, is the fundamental part of the engineering problem and therefore should merit most careful consideration. This part of the problem should not be left entirely to the engineering colleges, for they are unable to arrive at a complete solution. In the first place the engineering schools supply a very small number, perhaps less than one percent of the men required to carry on the business. In the second place their graduates are practically all led along one line to a single level. There are few college courses in salesmanship, foremanship, shop management, etc. Few colleges expect their graduates to become skilled mechanics, tool designers, or even draughtsmen. While the manufacturer of electrical apparatus needs a few highly trained men to carry on scientific research, he just as greatly needs laborers, skilled mechanics, efficient clerks, shop directors, inspectors of materials and hundreds of tradesmen, and all these need training to develop the best that is in each man for the direct benefit of the employer.

The educational activities in the vicinity of the Westinghouse interests at East Pittsburg divide themselves into two general classes: 1—The training of the graduates of engineering schools. 2—The training of non-technical men. The training of non-technical men is further divided into two distinct lines: 1—The apprenticeship system, which includes a certain amount of systematic class instruction given during working hours. 2—The night school, where attendance is purely voluntary. Both of these have a place in the training of non-technical men.

The Apprenticeship System—In the shop a certain section is devoted to the apprentices. This section is fitted with a complete equipment to furnish shop practice in all branches of the machin-

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*Condensed from a paper read at the 26th annual convention of American Institute of Electrical Engineers, June 28th-July 1st, 1909.

†Has been president of the Casino Technical Night School for several years and has recently been placed in charge of the educational division of the apprenticeship department at the Westinghouse works at East Pittsburg.

ists' trade. The boys are under the guidance of all-round mechanics taken from the shop organization and chosen for their interest in young men as well as for their skill as workmen. The boys remain in this section approximately two years. The latter half of their course is spent in the various sections of the shop.

In the classroom the instruction is provided on the Company's time, and is conducted throughout the four years of the course. Special rooms inside the works have been fitted up with suitable tables, desks, blackboards, etc., much the same as in an ordinary schoolroom. The atmosphere is hardly that of a school, but rather that of a class where the boys are given problems and explanations concerning the things with which they work every day, instead of problems in abstract mathematics. In connection with the character of the class work there are three vital points: 1—The scientific principles underlying the subjects must be taught. 2—The scientific principles can best be presented through the working of practical problems dealing with the things of the boy's everyday life. 3—The same problem must teach him certain facts and specific knowledge concerning the things with which he is working, such as weights, costs, and strength of materials, gear speeds, pulley and belt speeds, etc. In fact, a knowledge of the things with which the problems deal and the facility afforded for thinking about these very ordinary things may be the most valuable feature of this instruction.

There is another phase of the work without which all else will fail. For want of a better name, we call it spirit. It includes loyalty and enthusiasm, not only in the work and the future it holds for the boys, but also in all their daily relations with their fellows—a spirit of service and willingness, confidence in all things and all people and eternal optimism.

The Technical Night School—Six years ago a technical night school was started in the vicinity of the manufacturing interests at East Pittsburg. Its management is independent of any commercial industry, though its activity is encouraged and fostered by the local organizations, including the public school board, the latter furnishing the building. In the beginning there were half a dozen teachers and a few dozen students who attended classes in drawing, elementary mathematics, and shop practice. At present there is offered an opportunity for systematic study in such fundamentals as mathematics, mechanical drawing, mechanics, physics, theoret-

ical and applied electricity, chemistry, shop practice in both wood and metal, theoretical and applied steam engineering, etc. There is a faculty of 25 instructors and an enrollment of about 300 students. The instructors are not only versed in the theory of their respective subjects, but each is also actively engaged during the day with his subject within the organization of a commercial factory. The opportunities for obtaining exceptionally trained teachers are therefore ideal.

Attendance is voluntary, and a small tuition fee is charged. Admission is extended to all regardless of occupation or previous education. The low educational entrance qualifications are cared for by a preparatory department. Practically all of the students are employed in the various shops in this vicinity. Of the 45 men who have been graduated during the past three years, practically all have been steadily advanced in position and responsibility, and 40 are still with their original employers. Some of the students are doing high grade engineering work in the engineering department and in the drafting office of the nearby electrical manufacturing company. Others are successful salesmen and many are doing responsible work in the erection department and in the shop organization.

The engineering night school has a large field of activity. At the start its students have a clear idea of commercial practice such as is seldom possessed by the newly graduated college student. This early experience instills an appreciation of the value of time and of scientific training that tends to produce the most efficient student. They have learned several years earlier in life than the college student that scientific study and commercial practice not only go hand in hand but that they should continue hand in hand throughout life, if the highest achievements are to be attained; that there never comes a time when the one can be laid aside and the other taken up. They also know the importance of the routine of life, that from the office boy to the president, it is the fellow who gets the job done that gets the bigger job to do.

EXPERIENCE ON THE ROAD

TESTING AN ARMATURE FOR SHORT-CIRCUIT WITHOUT INSTRUMENTS

LEONARD WORK

THE armature of a direct-current motor which was used to drive a large exhaust fan had been sent to a machine shop for some minor repairs. While there an accident occurred which necessitated the replacing of a number of commutator bars and the writer was retained to supervise the work. The bars were in due time secured and substituted. It was then desired to test the armature for short-circuits before replacing it in the machine.

Now this shop was quite unused to electrical repairs and obviously unequipped for such testing. If a low reading ammeter, or a low resistance bridge had been available, the writer might have used one or the other for the purpose or, as a last resort, a battery, buzzer and telephone would have answered, but as the shop had

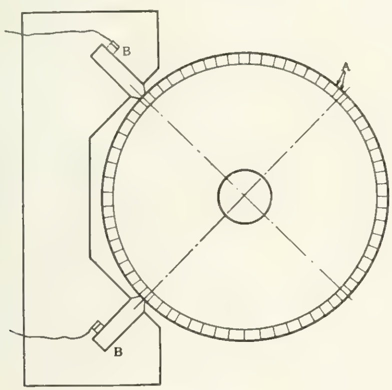

FIG. 1

none of these, nor were they to be found in the locality, some other means had to be devised.

It was noticed that the premises were lighted with alternating-current lamps and this suggested a way out of the difficulty. While this shop was devoid of nearly everything electrical, it could supply a piece of pine board which, with a couple of carbon brushes from the motor, was used to make an improvised brush holder, as shown in Fig. 1. With this and the lighting circuit, the test was made in a rapid and thorough manner. To improvise a brush-holder one

pair of two brushes were fitted in the wooden holder so as to maintain their normal position and distance apart on the commutator during the test.

In the present case, that of a four-pole machine, a thick piece of wood was roughly sawed out to span about half the circumference of the commutator and at one-quarter of this distance slots were made to hold the brushes at right angles to the bars. Each brush was tightly wedged in its slot and against a thin metal strip to which a lead was attached. When alternating-current was applied to the commutator through the brushes an electric-motive force was generated between adjacent bars and also at the points directly opposite. Now when any pair of bars at one of the latter points, as at *A*, was short-circuited with a piece of wire, a small spark was obtained, but, of course, when the bars were already short-circuited, no spark appeared. The brushes were held tightly against the commutator and while moving them forward tests were made at the opposite side of the commutator as far as convenient, when the armature was given part of a turn, and the process continued until the entire commutator had been tested.

This method of testing for short-circuits does not require any fine adjustment of current, but does use a rather heavy current which, however, is no inconvenience. Practically the full rated voltage of the armature may be applied in the case of a series wound armature without injury, if a lower voltage is not available.

In the particular instance described the line voltage was applied, except that, as a safeguard, some 30 feet of rather heavy iron wire was included in the circuit. The test showed a short-circuit existing between one pair of bars where solder had solidly united them, but which had defied ordinary inspection, thus proving the value of this apparently crude, but really excellent method.

A NON-REVERSIBLE MOTOR

N. E. FUNK

THE field rheostats for the alternating-current generators at the main station of the company with which I am connected are operated by shunt motors controlled from the operating table by reversing controllers. One morning, trouble developed in one of these motors as a result of which it refused to reverse and persisted in running in one direction on both positions of the controller. The controller was connected so as to reverse the motor

armature current, but for some unknown reason the motor did not respond to this reversal.

Selecting the controller as the most likely source of trouble it was found that one of the field fingers was not making contact. When this was repaired the trouble disappeared. Here was a motor operating at about normal speed with no field; but why? First, a resistance in series with the armature, as shown in Fig. 1, served to limit the current and the fuses were of such capacity that the current flowing through the motor circuit would not blow them. Second, the brushes were not on the neutral position, which gave the motor some demagnetizing ampere-turns which were in this case magnetizing, since there was no field to demagnetize, and accordingly the

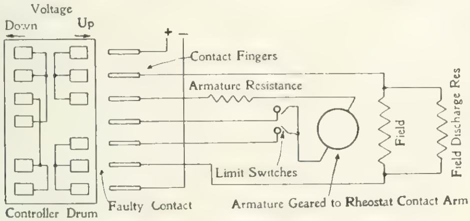

FIG. 1—CONNECTIONS OF MOTOR AND CONTROLLER

motor ran on the field produced by its armature current. When the armature current was reversed by the controller the field produced by the armature current also reversed and in consequence the motor ran in the same direction as before.

To prove this solution the armature of a small series motor was connected in series with a lamp bank and the field left disconnected. When the brushes were on the neutral position nothing happened, but by shifting the brushes from the neutral in first one and then the other direction, the armature could be made to revolve in the direction of brush shift. The direction of rotation was independent of the polarity of the supply current.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburg, Pa.

356—BURNING ON COMMUTATORS—In a local sub-station there are two 300-kw motor-generator sets. The generators are of 500 ampere, 600-volt size with commutating poles, and burned spots have developed at opposite sides of the commutators on both machines; burning seems to take place under the positive brushes, there being two positive and two negative sets. Both the commutators were cleaned by means of sandpaper mounted on a block, but the burned spots have returned. Serious sparking is apparently more liable to occur when the machines are first started in the morning, at which time the load is usually about 450 amperes, *i. e.*, nearly full-load. Please explain the cause and suggest a remedy for this trouble. H. E. M.

If there are spots on the commutator the trouble is in the winding or cross-connections, or there is local trouble in the commutator. As the machines have commutating poles, there should not be any sparking, provided the *connections are correct* and the poles are of the *correct polarity* for the direction of rotation. It may be found, upon closer examination, that there is a burned path around the commutator, due to unequal spacing of brushes, or, otherwise, resulting from failure to stagger the brushes so that those of opposite polarity trail each other. This is explained in No. 336, appearing in the Dec., '09 issue. Full information as to the nature of the spots, number of bars affected, whether the spots are in the diameter, etc., should be given in order to allow of comprehensive answer. L. A. M.

357—BOOKS ON GAS ENGINES—I wish to make a careful study of gas and gasoline engines. Please recommend some good books covering the subject. R. W. B.

The most satisfactory treatment of this subject is embodied in the work of Dugald Clerk on "Gas and Oil Engines." Price, $4.00. This book came out many years ago, and naturally does not deal with some of the more recent developments. It is, however, quite thorough on the underlying principles of this branch of the art. A later book on "Internal Combustion Engines," by Professors Carpenter and Diederichs, price $5.00, may serve your requirements. Another book dealing with this subject in a more simple manner and touching upon automobile practice, is "Audel's Gas Engine Manual," price, $2.00. This was reviewed in the JOURNAL for February, 1909, p. v. E. D. D.

358—COMPARATIVE FUEL CONSUMPTION OF PUMPING EQUIPMENTS—What will be the comparative fuel consumption of pumps to raise 300 gallons of water per minute against a head of 125 feet, under the following conditions: 1. A simple, non-condensing, direct acting duplex steam pump. 2. A power pump geared to and operated by a simple non-condensing steam engine. 3. A power pump geared to and operated by an electric motor, the small generator to supply electric current for the motor to be operated by a simple non-condensing steam engine. C. P. K.

In general, either of the latter two propositions would be more favor-

able from the standpoint of fuel consumption. In both of these cases the fuel cost chargeable to the pump would be the same, for, while the engine driving the main generator considered in the third case might represent better performance, as regards steam consumption, than the smaller engine direct-geared to the power pump, the saving would probably be offset by the electrical losses in the generator and motor. Owing to the extravagant use of steam in a direct acting steam pump, at least 33 percent greater coal consumption is to be expected than in case *2* or *3*. Local conditions, however, relating to the first cost of the different styles, convenience of each arrangement, and the use of exhaust steam for feed water heating, should be carefully weighed in the choice of a pump. E. D. D.

359—Efficiency of Application of Electric Radiators — After reading the article on "The Efficiency of Illumination" in the March, 1909, issue of the Journal, I understand from the curves showing light efficiency and temperature, that the same curve would be applicable to the radiator, *i. e.*, that if a radiator made of iron were raised to the temperature just below visible heat, this temperature would be the most efficient to run as a heat producer. Also, please explain why different heating apparatus have different efficiencies. Is it because of the different methods taken to conduct the heat from the active or line conductor to the working conductor? I fail to see how, by using different materials, different efficiencies would result when the heat produced in any conductor by electricity is proportional to the power consumed, C^2R. A. A.

There is a difference in efficiency of an electric heater as a heat producer at various temperatures. While it is true that the efficiency of conversion is always 100 percent, there is another factor which must be considered and that is the efficiency of use of the heater. In other words, while we always secure 100 percent efficiency from the heater as a user of energy, we seldom if ever equal this value when we consider the uses to which the heater is put. In order to distinguish between the conception of efficiency of the heater and the efficiency of the heat application, the expression *effectiveness* may be used to express the practical working value of the energy produced. If, for instance, a water heater of the immersion type is used to heat water to the boiling point, while 100 percent of the energy used would be converted into heat, an efficiency of probably only 90 percent would be secured when considered as the amount of the energy which would be accounted for as absorbed in the water itself. If this distinction is carefully borne in mind, it will save many perplexing questions. Therefore, considering the first part of the question, while the efficiency of an electric radiator as a heat producer would always be the same, the effectiveness of a radiator as a heat distributor would be different at different temperatures. This difference would be governed by the relative value of the radiation and convection factors; hence, the statement that the effectiveness is greater as the temperature is raised is correct. It should be further noted that radiant heat transmitted without reference to convection currents, is a form of energy which can be transmitted in any direction desired, with minimum loss, and the problem to be developed in the effective warming of rooms is not to heat the air but to supply heat energy in a form that may be absorbed by the objects in the room, they in turn becoming radiators and keeping the temperature of the air at the top of the room at a minimum. The last part of the question is answered by the comments previously made, *i. e.*, the efficiency of application depends on the type of the heater and the skill with which it is applied. As an example of what this may mean, if a pan containing water is put on an electric stove, it is seldom possible to obtain an effectiveness of more than 50 percent of the energy used. If an immersion type of heater is used, that is, one

which is placed in the water and in which the losses are only those of radiation and convection from the walls of the containing vessel, an effectiveness approaching 90 percent is obtained. As a further example, placing in a cube, say six inches on a side, any type of electric heater, with any form of resistance, insulation, or method of fastening to the walls of the cube, the same surface temperature will always be obtained with a given amount of energy, though this temperature may not be reached, in each case, in the same time. W. S. H., JR.

360—CHARGING CURRENT ON HIGH-TENSION TRANSMISSION LINE—Our company has recently started to operate a 50 mile, 66 000 volt, three-phase transmission line. A 1 000 kw, 2 200 volt generator, 262 amperes per terminal, supplies the power. The high-tension ammeters indicate that the charging current without load is ten amperes per phase. If the lines were delivering full-load, half-load, or less, would the charging current be less than at no-load; or, would it be the same, *i. e.,* is the charging current a constant quantity depending on the constants of the transmission line, independent of the load; or does it vary with change of load, and if so, how? The ratio of transformation is 30 to 1; hence, according to the above figures, the generator would have to carry a load of 300 amperes per phase to charge the line. It is evident, then, that the generator is thereby overloaded 38 amperes per phase more than its rated full-load capacity. If a motor load of say, 75 kw is carried at the end of the line, will this raise the current output of the generator?

Assuming such additional dimensions as may be required to calculate the charging current for a transmission line such as that in question, and making calculations on this basis, it is evident that a charging current of approximately ten amperes is probably not unreasonable. The effect of this charging current is to overload the 1 000 kw generator about 15 percent. The amount of the charging current for a given transmission line is fixed regardless of the load; but, the ammeter reading *may* decrease when the line is loaded with inductive apparatus such as induction motors. The magnetizing current of the motors is a lagging current which tends to neutralize the line charging current, as the latter is a leading current due to the electrostatic capacity of the line. If the two were equal in value, a power-factor of 100 percent would be obtained and only the working current would flow. If there were sufficient inductive load to do this, in the form of induction motors running light, the meters would read approximately zero, as the load current would then be only that required to supply the losses of the motor, and, of course, would be very small. This will be understood when it is considered that that component of the generator current which is required

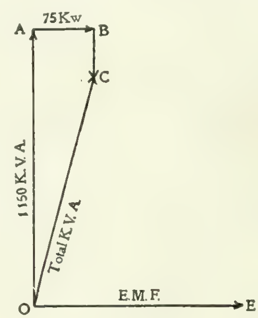

FIG. 360 (a)

OA = Apparent power required for line charging current = 1 150 k.v.a.
AB = Power input to motors = 75 kw
BC = Wattless input to motors (excitation and leakage).
OC = Total k.v.a. to generator.
Direction of rotation of vectors from *OE* toward *OA*.

to charge the line is a leading current, *i. e.,* tending to decrease the power-factor by advancing the phase of the main current relative to the impressed e.m.f., and the exciting current of the induction motors (which represents the inductive load referred to above) is a lagging current, *i. e.,* tending also to decrease the power-factor but, in this case, retarding the phase of the main current

behind the impressed e.m.f. The effect of an induction motor load of 75 kw [Fig. 360 (a)] would of course depend somewhat on whether it represented losses in large motors running light, or input to small induction motors themselves carrying full load. See No. 366 in present issue. In general, however, a load of this capacity would raise the power-factor somewhat, but probably would not be sufficiently great, relative to the total capacity of the system, to produce a noticeable difference in the ammeter reading.
H. M. S.

361—CONNECTING WATTMETERS — In measuring power in a three-phase, 60-cycle, 220-volt circuit, in which the power-factor was approximately 75 percent, by means of two single-phase indicating wattmeters, I encountered difficulty in getting them to read properly. The meter in line *A* read correctly, and also that in line *C*, when the motor was running light, but when heavy load came on the meter needle would indicate a negative load. The potential coils of the two meters were of course connected in common to line *B*. By interchanging the potential leads of the second meter (*i. e.*, in line *C*) the deflection was reversed. The phases were as nearly balanced as possible. Please explain the cause of the negative deflection on heavy load when the deflection was positive on light load. Are the connections as first made correct, or should they be reversed to give positive deflection on heavy load, regardless of the indication on light load? Would not the power in the circuit be the sum of the two readings? H. W. R.

The method of determining the proper connections of indicating wattmeters on a three-phase circuit, applicable either for two single-phase wattmeters or a polyphase wattmeter, regardless of the power-factor of the load, is given in an article on "Polyphase Wattmeter Connections" by Mr. M. H. Rodda, in the JOURNAL for July, 1909, p. 436. It should be noted that an induction motor may show a power-factor of 50 percent or less in case of considerable overload, as well as on light load, especially in the case of motors of small capacity. If, then, the load being measured were made up largely of such motors, a condition of low power-factor might be involved, such as considered by Mr. Rodda, and would require the method of procedure described in this article, in order to insure correct connection of the meters for measuring the power in the circuit. H. W. B.

362—EFFICIENCY AND POWER-FACTOR OF INDUCTOR ALTERNATOR — How do the efficiency and power-factor of inductor type alternators compare with those of a standard revolving type machine? What are the general features of this type of generator? W. S. D.

The efficiency of the inductor type generator compares favorably with the standard types of alternators in common use. The power-factor is a characteristic of the load, not of the machine. The comparative efficiencies, however, depend entirely upon the design of both machines and is more or less a question of cost. In general, the inductor type machines are the heavier. At low power-factor the regulation of the inductor type of machine is not as good as in the standard type. The essential feature of the inductor alternator is that iron only is revolving. In this type of machine none of the copper conductors move, the only moving parts being masses of iron whose motion sets up variations in the magnetic flux. Magnetic leakage plays an all-important part in the design of the inductor alternator. If there be much leakage from either armature or field, the machine becomes defective in regard to voltage regulation. By working with a very small air-gap, not much greater than the necessary clearance, and by careful design of both armature and inductor, magnetic leakage in these machines is reduced to a very small amount, and the whole magnetic field is very stiff and concentrated. The armature of an inductor type ma-

chine must work at a higher flux density than is usual in alternators of the ordinary types. That is to say, the armature is magnetized, not below the bend of the magnetization curve, but on it. Consequently, if the air-gap is very small, and comparable with the reluctance of the armature iron, the increase of excitation necessary to make up for the drop in pressure at full-load becomes large, as a considerable increase of excitation will not cause a corresponding increase in the field (and hence in the terminal voltage) but will raise it by only a small amount. A machine of the inductor type, which must work at high flux-densities on account of economical considerations, must have a small air-gap if even reasonably good voltage regulation is required, and becomes very inflexible, especially on induction motor loads, which are usually of very low power-factor.

J. B. W. and L. W.

363—Single-Phase Connections on Three-Phase Circuit — The above diagram was brought to my notice. I take it that the argument applied to other arrangements for obtaining single-phase power from polyphase circuits would likewise apply to this, viz., that polyphase power is constant while single-phase power is pulsating and therefore it is not possible to transform from polyphase to single-phase. Please advise more in detail. C. I. Y.

The above arrangement does not transform from three-phase to sin-

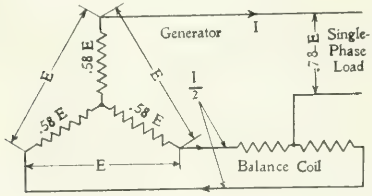

FIG. 363 (a)

gle-phase; it merely causes a certain distribution of the single-phase current through the three-phase system. The balance coil serves to force the current to divide equally, thus making of two wires on the three-phase system a return circuit for the third wire. If 87 percent of line voltage is sufficient, this is probably as good as any method of taking single-phase load from a three-phase generator. The current and voltage relations are shown in Fig. 363 (a). If, however, full line voltage is required, equally good results would be obtained by putting the load across any one of the three phases, thus eliminating the balance coil. As noted in No. 299, September, 1909, a demonstration that it is impossible to obtain efficient operation and balanced conditions is given in an article appearing in the Journal for February, 1909, p. 43. E. C. S.

364—Determination of Power-Factor—Can the power-factor of a circuit be figured accurately by taking the voltage and ampere readings on hot wire instruments and the kilowatt readings on induction type instruments? W. S. D.

Power-factor may be determined according to the formula P-F = watts ÷ volt-amperes. The hot wire instruments would of course eliminate any inductive effect in the wattmeter reading. The induction type wattmeter would likewise give correct readings. It is not necessary, however, to use hot wire instruments for the determination of the kilowatt reading; this can be obtained by means of a voltmeter and ammeter of the induction type, for example, provided the instruments are designed for the voltage, current and frequency of the circuit in which the power-factor determination is to be made. H. W. B.

365—Transformer Ageing and Distribution of Load—If a spare transformer for two banks of three single-phase transformers connected up for three-phase operation, either star or delta and of similar capacities is out of commission for some time, for instance, a few years, would the ageing effect of those in service interfere in any way with the distribution of the load between the spare and the other transformers, if

it is used to replace one of the transformers in the banks? A. A.

The proper division of load between the transformers operating in parallel is a function of the regulation characteristics of the transformers, namely, of their resistances and reactances. Perfect parallel operation is obtained when the relative resistances and reactances of the several transformers grouped in parallel are the same. It follows then, that transformers which are initially the same will properly share their joint load when operated in parallel even though the iron losses be different. In an extreme case, beyond any probability in practice, it might be possible to slightly effect parallel operation because of the excessive magnetizing current demanded by the inferior units as compared with that required by the normal units. K. C. R.

366—POWER-FACTOR OF INDUCTION MOTOR LOAD—What power-factor should be expected in an industrial circuit supplying power to induction motors only? W. S. D.

In such a case the power-factor would depend on whether the motors were carrying full load or only light load, as the power-factor of induction motors varies from no load to full load. Accordingly, the average power-factor of the circuit will be dependent, at any time, on the ratio of the actual load to the total capacity of the motors in operation. The smaller the load on the individual units and the larger their number for a given capacity, the lower will be the power-factor. In a large steel mill recently constructed, in which electric drive is employed, an average of 70 percent power-factor was obtained. The average industrial circuit should show a power-factor of 60-70 percent where proper care has been taken to select a motor of proper capacity for each application. Where this is not done, and the various driven machines are "overmotored" (*i. e.*, provided with motors larger than necessary) the power-factor will fall considerably below this figure. When, after careful attention has been given to proper application, and the power-factor of the system is still too low to allow of satisfactory operation of the generators in the power-house, advantage may be taken of the method of power-factor correction by the use of synchronous motors as described in the article by Mr. Wm. Nesbit, in the JOURNAL for August, 1907, p. 425. The required calculations for a given case may be made graphically by the method described in an article by Mr. Chas. I. Young, in the JOURNAL for November, 1907, p. 627. See also No. 353 in the Dec., '09 issue. It is, however, not wise to attempt to obtain high power-factor by application of this method of correction without first having given careful attention to the arrangement of the induction motors involved. G. H. G.

367—FUSES WITH INDUCTION MOTORS—(a) When running fuses are used on induction motors, what maximum size of fuse would be allowed, expressed in percent of full-load running current? (b) Would running fuses be required on any size of single-phase repulsion type motor? (c) Please give an opinion on the use of running fuses immersed in oil, as sometimes practiced? K. N. A.

(a) The maximum size of fuses allowable in the running circuit should be determined by the guarantee of the manufacturers of the motor in question. The standard guarantee recently adopted by the American Motor Manufacturers Association is, 25 percent overload for two hours. A fuse which will carry this maximum guaranteed load without blowing (see rule 53, Rating of Fuses, Nat. Elec. Code) should be selected. (b) Running fuses are desirable on all motors, as any machine is liable to overload. (c) In placing fuses in oil the following disadvantages must be considered: 1. Tendency of oil to conduct away heat, thereby necessitating small fuse wire for large current. 2. Convection currents in the oil due to heating near fuse cause blowing point to be uncertain. 3. Oil fuses with central portion arranged to be above the oil level are uncertain, owing to great variation being caused in the blowing

point with slight changes in oil level. 4. Possibility of dangerous explosions. 5. Cumbersome and more expensive design. C. H. S.

368—OVERLOAD CURRENT CARRYING CAPACITY FOR INDUCTION MOTOR CIRCUITS—What percentage additional copper carrying capacity above that for full-load current would be required on squirrel-cage type induction motors with compensating device and without compensating device, either two or three-phase? What percentage on single-phase repulsion type motors, and what percent on single-phase motors with coils? K. N. A.

The name plates of alternating-current motors give the full load current in amperes per terminal and the National Electrical Code specifies that an additional allowance of 25 percent be made in the current carrying capacity of the wiring for these motors. This percent allowance, however, is not always used. For instance, some cities specify that this increase shall be 50 percent, while a few electric light companies compel the use of a wire not smaller than a No. 6, B. & S., regardless of the size of the motor. For single-phase repulsion type motors, provided with starting devices, the 25 percent allowance called for by the Underwriters is usually sufficient. For polyphase, squirrel-cage induction motors, without starting devices, and single-phase induction motors with starting coils, it is advisable to lay out the wiring for a current 50 percent greater than the full-load value. In any given case, the starting conditions of the motors should be taken into consideration, as, of course, the wiring for a motor starting under excessive overload should be more liberal than that for a similar motor starting under light load. T. W.

369—ASBESTOS IN AIR SPACE OF BOILER SETTINGS—Is it possible to obtain information in the form of Government publications, covering the matter of using asbestos in the air space between the inner and outer walls of boiler settings, as referred to in article on "Power-House Efficiency" by Mr. R. A. Smart, in the JOURNAL for April, 1909, p. 209? Is there full authority for this practice? H. R. B.

The use of asbestos between the inner and outer walls of boiler settings is indorsed by the Government Testing Bureau after thorough experimentation. If it were possible to keep the inner and outer walls tight, there would be no question but that an air space would be the best insulation. It is, however, a safe statement that no boiler setting in existence is impervious to the passage of air. This being the case, it is desirable to prevent the circulation of air through the inner space, and asbestos has been found suitable for this purpose. The United States Geological Survey has a bulletin in process of publication at this time, to be entitled "The Flow of Heat Through Boiler Settings," by Messrs. Ray and Kreisinger, which will give further information on this subject. R. A. S.

370—Co_2 TEST FOR FLUE GASES—Please give further information regarding sampling apparatus such as that shown in the illustration on p. 209 of the JOURNAL for April, 1909, in the article on "Increasing the Efficiency of Factory Power Houses." Please give simple instructions for making a recording Co_2 gauge. C. A. T.

Ordinarily, samples of flue gases are taken for a short period of 15 to 30 minutes' duration and analyzed by some sandard method, of which the Orsat method is a good example. The apparatus furnishes the percentages of CO_2, CO, O and N within a reasonable degree of accuracy. The sampling apparatus referred to on p. 209 of the April issue, provides for the drawing of a relatively large sample, the rate of drawing being such as to continue the sample for a period of about 12 hours. Such a sample would represent average conditions rather than momentary conditions. In common with all sampling bottles, the carboy is first completely filled with water and then drained slowly by means of a siphon,

the empty space being filled with a sample of gas by means of a pipe connecting with a suitable point inside of the boiler setting. We know of no simple recording CO_2 analyzer; this apparatus is necessarily of complex construction. As pointed out on page 207 of the April issue, a knowledge of CO_2 alone is apt to be misleading unless accompanied by a knowledge of the percentage of CO. References which may be found of interest in this connection are a paper by Mr. R. S. Hale, on "Flue Gas Analysis"; Trans. Amer. Soc. Mech. Eng. Vol. XVIII, p. 109; and Hemphills "Methods of Gas Analysis." R. A. S.

371—Relays on Induction Motors—What are considered to be the requirements for low voltage release and over-load devices in connection with induction motors? K. N. A.

The overload at which a motor circuit breaker should open the circuit depends almost entirely on the nature of the load, *i. e.*, the demand on the motor. Some standard automatic auto-starters have a tripping range of 85-200 percent on the running side, and this would seem an ample range for ordinary practice. For special cases the nature of the load and the guarantees of the motor are the best guide. Low voltage releases should be used in connection with each induction motor circuit breaker when a decrease in speed, due to drop in voltage, is not permissible. The low voltage release is also used to open a motor circuit in cases where the line may lose its voltage for a sufficient length of time to allow the motor to drop its speed to a point where it will draw a sudden and large starting current when the full voltage again comes on the line. Manufacturers ordinarily specify that motors should not be operated on a voltage lower than ten percent below normal. C. H. S.

372—(a) During a test on insulating oil with a gap of 0.15 of an inch, the first discharge across the gap was at 15 500 volts, after which the voltage was increased to 38 500 before complete breakdown took place. Should the first discharge across the gap be taken as the true test or the point where the discharge becomes continuous?

(b) It is recommended in one of the electrical papers that no oil testing less than 15 000 volts with a ⅛-inch gap should be used. Does this apply to the permanent breakdown point?

(c) Is the first discharge at low voltage caused by impurities and small fibres from the filtering cloth, which have a tendency to line up between the balls and form a conducting path, or is it due to static discharge? G. MAC R.

(a) If the first discharge does not blow the fuse or open the circuit breaker in the primary circuit of the testing apparatus, it may be disregarded. Sometimes foreign particles are expelled by this first discharge without a sufficient amount of current passing to open the circuit breaker.

(b) The reference to the maximum voltage of 15 000 probably means the average of about ten tests taken on the same sample of oil, each of which opens the circuit breaker or blows the fuse. This limit, however, seems too low. It is rather difficult to compare the results of tests using a ⅛-inch gap with those using a gap of 0.15 of an inch. It would seem best not to use the smaller gap on account of the greater liability of accumulation of air bubbles between the balls.

(c) When the first continuous discharge occurs at low voltage and all of the others of the series of tests on the same sample are considerably higher, the general cause of the difference is the presence of minute air bubbles which cling to the balls when they are first inserted in the oil. They are first driven into line between the balls by the strong static field and are afterwards expelled by the arc of the first discharge. In this connection see an article on "Transformer Oil," by C. E. Skinner, in the Journal for May, 1904, p. 231. In order to obtain satisfactory results in testing it has been found necessary to observe the fol-

lowing precautions: After filling the oil cup the oil should be thoroughly agitated and allowed to stand until the air bubbles have had time to rise to the surface. This can best be determined by holding the cup between the eye and a strong light. After each test the thumb screw should be loosened and the oil stirred by raising and lowering the upper terminal, taking care not to raise the ball above the surface of the oil. Should this occur air bubbles are sure to be carried down with it. This stirring will suffice to keep any water or other foreign particles mixed through the oil, but the presence of air will not be a disturbing factor. Ten tests on each sample of oil should always be taken and the average of these should not be below 30 000 volts for a striking distance of 0.15 of an inch. As will be observed by the example given, much higher results than these are frequently obtained. In case the results of any one of the ten tests after the first varies greatly from the others it should be checked as it is highly probable that some error has occurred in taking the reading or in setting the gap, or that air has been carried into the oil when agitating it. When the foregoing precautions are carried out it will generally be found that the maximum and minimum breakdown points are not very far from the average, as is shown in two examples taken at random from reports on routine tests on samples of oil, as follows: Maximum 58 000, minimum 50 000, average 54 000; maximum 58 000, minimum 46 000, average 51 000; gap used, 0.15 inch; number of breaks on each sample, ten. J. E. M.

373—Short Bends on Lead-Covered Cables — When installing paper-insulated lead-covered cables for use on circuits of 2 000 volts and above, what is the shortest bend that can be made without injury to the paper insulation? I understand that there is a formula covering this. J. A. R.

The general rule is to limit the bend of cables to a radius of not less than 10 times the diameter. In very warm weather, of course, it is safe to bend cables to a less diameter than this because the insulation is not so apt to crack when softened by the heat. H. W. F.

374—First Aid for Flashed Eyes—Please give first aid treatment for flashed eyes. We desire to have a supply of the remedy on hand for emergency. Are boracic acid and cocaine injurious? C. H. D.

An efficient eye water for use in the treatment of flashed eyes may be made up at any drug store according to the following formula:

℞ Sodii Biboric.	.30
Acidi Boric.	.15
Alum Sulph.	.06
Zinci Sulph.	.06
Aq. Camphorae.	30.
M.	

As a first aid this solution may be freely used; and may be continued every one or two hours until recovery. Other measures are: Adrenalin Chloride $\frac{1}{10\,000}$, a fresh solution being prepared for each instance; ice water compress, changed every minute or two by the patient, and continued for one-half hour or longer. A saturated solution of boric acid in sterile water, preferably compounded by an apothecary, will also be found efficient, but the above formula is superior. Cocaine used continuously softens the epithelium and retards recovery, and is not a remedy of election in these cases. Moreover, the three percent solution of cocaine, as employed in general eye work, in many instances causes great pain. C. A. L.

375—Measurement of Induction Motor Load—In measuring the power-factor of an induction motor load, would it be permissable to assume a balanced condition in the windings and to take readings for power with one single-phase wattmeter? C. R. F.

Unless measurements of great accuracy are required, it may be assumed that the power-factor is the same in each phase. There is usually a small but measurable inequality of power-factors on the different phases. H. W. B.

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Absorption Dynamometers

Most of the text-books relating to experimental engineering treat of the "Prony" or friction band brake as a power measuring apparatus. The practical use of this device is, almost without exception, a part of the training of every student of mechanical or electrical engineering. The principle of its operation is easy to understand, because we can actually see that the constant resistance of the friction of the brake band is being overcome through a definite distance every minute, and a resistance overcome through space is our fundamental conception of work. The work absorbed by the friction appears as heat and is carried off by a spray of water playing on the brake wheel.

This device is eminently satisfactory so long as the heat generated per square inch of rubbing surface is not excessive. Experience indicates that 325 British thermal units per square inch per hour is about the maximum permissible. As the heat equivalent of one horse-power for one hour is 2 545 B.t.u., this means that we must have approximately eight square inches of friction surface for each horse-power absorbed.

The power of the average prime mover has of late years grown to such large proportions that an ordinary Prony brake for measuring the output would involve dimensions that are prohibitive. With the high speeds common to turbines, the diameter of the brake wheel, to avoid dangerous rim speeds, must be so small that it is impossible to get a reasonable area of rubbing surface, and the heat evolved is so concentrated and intense that it is impossible to control the temperature, and the apparatus is quickly destroyed.

The water brake, or more properly speaking the hydraulic dynamometer, is the child of necessity; and very little of its biography has as yet been written. In the first attempts to produce a dynamo-

meter of this type, designers could not divorce themselves from the idea of *friction*. The earlier machines had a series of discs like toothless centrifugal saws revolving in compartments in a stationary casing partially filled with water. The underlying conception was the absorption of the power by the skin friction between the fluid and the metal. We now have a much broader conception of the matter, viz., that the work done in stopping a moving body is exactly the same as that which set the body in motion.

By referring to the article in this issue describing the large hydraulic dynamometer designed and built for testing the Melville and Macalpine reduction gear for steam turbines, it will be seen that the rotor is designed with special reference to imparting a rotary motion to the fluid in the casing, and the latter is designed with special reference to stopping this motion. The water enters the casing in an axial direction and consequently can have no rotary motion until it is imparted to it by the rotor of the dynamometer. The water leaves the casing through radial ports, and therefore all of its rotary motion must have been destroyed, or it could not escape. It is not necessary that the fluid be brought to a state of absolute rest, but only that it shall have no velocity in the direction imparted to it by the rotor. Whatever the velocity may be at right angles to this direction is immaterial.

The casing is free to revolve on the shaft except for the resistance of a projecting radial arm bearing against a platform scale, and the pressure at the end of this radius arm multiplied by the distance from the center of the shaft to the point where the radius arm bears on the scale, is the moment of the force exerted in accelerating and retarding the fluid.

It may be argued that we are simply measuring a force, and as the force is stationary, we consequently have no measure of work. Motion, however, is a relative thing, and depends on one's viewpoint. If an observer could have gotten a secure and comfortable perch on the revolving shaft of the dynamometer during the full-load test of the reduction gear, he would have seen the weighing apparatus traveling around a circle 13 feet in diameter 300 times each minute, pushing against the radius arm of the casing with a force of some 4 000 pounds. He would then feel satisfied that the 6 000 horse-power was a real tangible thing.

H. E. Longwell

Developing Central Station Power Business

The article on "Industrial Engineering by the Central Station," in this issue, is refreshingly conspicuous by reason of Mr. Parker's liberality in sharing with his co-workers the credit for the excellent methods and results obtained by the Rochester Railway & Light Company in securing new power business. He refers first, to the success of Mr. Dudley's investigations and recommendations, which resulted in greatly improving the operating condition of a motor-driven foundry; and directly following this he refers in a complimentary manner to Mr. Peck, chief assistant in their engineering department, and closes with a very commendable reference to the co-operation and assistance of their entire engineering force. It is not an unknown occurrence for central station managers and heads of departments to appropriate the entire credit for the results obtained by hard and faithful work by the men under them. Only recently a promising and energetic young man, who in two years had greatly increased the income of the company by whom he was employed, resigned for the reason that he received no credit for the work which he was doing, and had no prospect of advancement with his company. The manager was new at the business and very dependent upon the young man, and could have retained his services for years had he been willing to share the credit of their successes, instead of calling the attention of his directors to what he, personally, was accomplishing.

If all central stations would follow the liberal policy outlined by Mr. Parker, and adopt his motto, "It being our belief that we should sell utility rather than power, i. e., that we should endeavor to make each kilowatt-hour sold produce the maximum value to the customer, even though the number of electrical units disposed of is thereby reduced," the electrical business would soon be revolutionized.

The writer would suggest that if investigation were made at stated periods before the customer became dissatisfied or in danger of discontinuing service, it would be even more effective than the method mentioned by Mr. Parker.

The idea of placing the important points in the first paragraph of a report is a good one, but in some cases where the actual saving in cost of operation is slight compared with the ten or fifteen percent increased output, decreased cost of insurance, increased reliability and flexibility of service, etc., the proposition should be

modified to emphasize the most striking incidental features applying to the particular case.

The larger companies naturally have the advantage of the smaller ones in securing new power users, inasmuch as their business will justify the maintenance of a competent engineering staff to work out these points to a nicety, but even they do not always realize the importance of this branch of their business, and often have not been willing either to train or employ specialists for this work. And specialists are required, as all good engineers are not capable of preparing practical propositions of this nature which will appeal to the layman, without receiving some special training and acquiring some knowledge and enthusiasm as to the possibilities from the central station standpoint. However, rapid strides along this line have been made within the last two years and many of the smaller central station companies, with the assistance of some of the larger manufacturing companies which have come to realize the importance of this movement, have organized departments for this purpose and are continually training men who are placed at the disposal of central stations and, in addition to their efforts to sell electrical apparatus, actually make tests and work up and submit comparative engineering reports, which assist central stations in securing more business and also enable smaller companies to keep a fair pace with the larger ones. Some of the larger concerns are combining the efforts of their specialists with those of the manufacturers, and thus obtaining even better results. A number of the leading electrical journals are cooperating by publishing valuable information along this line, thus presenting excellent opportunities for the interchange of ideas and information. The natural tendencies are toward the centralization of power interests and the next few years will undoubtedly witness some wonderful results along this line.

Mr. Parker is to be congratulated not only for having a most interesting paper, but for having acquired the spirit of one of the most interesting and what will soon become one of the most important features of the electrical business. It is work of this kind which will prove the salvation of many companies which for years have barely been holding their own, by enabling them to increase their earnings with little or no investment. Central stations should consider no project too large to try for; if the business is not secured this year, it may be the next.

W. B. Wilkinson

Space Economy of Single-Phase Motors

At the last meeting of the American Institute of Electrical Engineers in the auditorium of the Engineering Building, New York, Professors Franklin and Seyfert read their paper on "Space Economy of Single-Phase Railway Motors." The principal point in the paper was the proposal to move the commutator outside the usual space occupied by that type of motor to a position on the outside of the frame, and to make use of the space thus rendered available foı a longer iron core and longer armature conductors.

It was proposed to accomplish this by making the armature the stationary member and mounting it external to the field. The commutator was to be mounted outside of the motor frame and was to have its brushholders rotated by a system of bevel gears.

A second point in the proposed plan was the use of balanced choke coils as a substitute for the customary preventive leads between the commutator and the armature windings. The first point mentioned, that of the external commutator, was the one upon which the authors laid most stress. Some results of calculations by the authors, on a particular motor intended to go in the same space as the motors on the passenger locomotives of the N. Y., N. H. & H. R. R., were given and the statement made that approximately sixty percent greater capacity could be secured by the employment of such a plan.

The discussion that followed was not very general, being participated in by Mr. E. H. Anderson, and Mr. E. F. W. Alexanderson, of Schenectady, and Mr. S. M. Kintner, of Pittsburg.

The trend of the discussion indicated a lack of agreement with the authors in their principal claim. It was urged quite strongly that such a construction would not prove commercial, as it tended away from simplicity and introduced elements that made the whole motor less reliable.

It was plainly shown that accepting the authors' figures, there was no gain in more economical working of material, the gain planned being almost in direct proportion to the amount of increased active material, copper and laminated iron. Attention was also called in the discussion to the fact that insulation allowances were too small and one speaker questioned the authors' ability to get the proposed increased length of core in the space available after suitable allowance had been made for all connections and for the bevel-geared drive of the brushholders.

Some general discussion, not bearing on the special points of

the paper, was presented by two of the speakers and this should prove of interest to those studying the space economy of motors for railway purposes.

It is worthy of note that after almost seven years' development of the single-phase motor, there has not been any material departure from the type of motor proposed by Mr. Lamme in his paper read before the A. I. E. E. in 1902. Such changes as have been made are more in the nature of detail refinements, or extensions of certain design constants which actual experience in service have shown to be desirable. Although various radical modifications in type have been proposed from time to time, both in this country and abroad, yet commercial practice adheres very closely to the initial and simple type.

The Franklin and Seyfert paper gives a very interesting study of a possible way to economize in space, but judging from the discussion, fails to supply a workable plan for a motor that would prove reliable.

S. M. Kintner

Some Advantages Incident to Electrification

In view of the recent decision of the Illinois Central Railway not to electrify their Chicago terminals at this time on account of the cost, the experimental features and the difficulties involved, the article by Mr. Darlington in this issue is most timely. It brings out points concerning the electrification of steam railways that have not hitherto received the attention they deserve. Some of the economies which can be secured by proper electrification of large terminals are only briefly pointed out, but they open up vast possibilities. In our large cities where land is so valuable the practicability of erecting buildings over all tracks will in itself go a long way toward paying for the cost of the electrification. The plan of double-decking the tracks, as introduced in the Grand Central Station in New York, is applicable not only to passenger stations, but to freight stations and warehouses, and even as a means of reducing the required width of the right of way where land is very costly.

It seems strange that more attention has not been given to the cost of local transportation to and from the railroads when it is well known that this oftentimes amounts to more than the cost of hauling freight by rail for hundreds of miles. The steam railroads have seemingly been unable to handle this traffic economically and have,

therefore, left it for local development, but the introduction of electric operation gives an entirely different aspect to the matter. Terminal facilities can be brought to the highest efficiency only by electrification, and the same may be said of local transportation of both freight and passengers.

The matter has now reached the point where it can be stated with certainty that practically any class of traffic may be handled satisfactorily by electricity, and it is entirely unneeessary for any railroad to delay electrification because of any doubt on this score. There are still some experimental features, it is true, but the successful handling of trains of every weight and at every speed by means of electricity is an accomplished fact.

N. W. Storer

Government Specifications

The presentation of the paper on "Government Specifications for Electrical Apparatus," which appears in this issue of the Journal, was followed by a discussion by a number of men connected with various bureaus of the Government, which are purchasers of electrical apparatus, and by several representatives from the Bureau of Standards. Various instances were cited showing some of the particular difficulties which exist in the making of specifications and the acceptance of apparatus through the official channels of a large Government, which are quite different from those elsewhere.

The readiness of the Bureau of Standards to lend its services to other departments in the broadest and most efficient way was marked. This Bureau is doing most excellent scientific service in the matter of refined standards of measurement, and it is beginning a service in connection with commercial and engineering standards which may become of equal efficiency and importance. The two kinds of service are distinct and different. In one the closest approximation to absolute accuracy is the aim. In the other, the object is not perfection, but adequacy; it is to get suitable apparatus and to get it cheap. In the one case, the best is not quite good enough; in the other, what is good enough is best.

The whole discussion was devoid of acrimony and was in the nature of constructive criticism in an endeavor to secure the best ultimate ends. It is understood that the paper will be published in the Professional Memoirs of the Engineer Bureau, United States Army, accompanied by the discussion.

Chas. F. Scott

USES OF REINFORCED CONCRETE IN RAILWAY AND POWER HOUSE WORK

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THE purpose of this paper is to present and outline the possibilities of reinforced concrete in certain fields of construction work with which the electrical engineer comes in close contact. The writer assumes that the reader is familiar with the finished structure of reinforced concrete, but not with the details of design or construction. Concrete has for some time been a common structural material. Its value was long limited to foundation work, since it was adapted especially to such work as required stability and permanence. Within recent years, however, concrete has, step-by-step, supplanted various building materials for certain uses until it has come to be used for practically all purposes for which other structural materials are suitable.

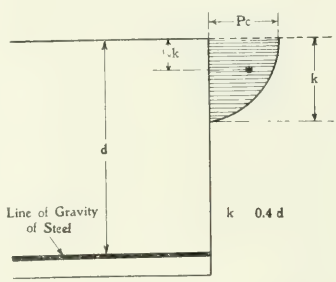


FIG. I—DIAGRAM OF ASSUMED STRESS DISTRIBUTION IN A SIMPLE REINFORCED CONCRETE BEAM

The most notable development in its application has been brought about by the addition of steel reinforcement. This has allowed of taking the most important step of all, viz., the replacement, in many cases, of structural steel. It is not contended that reinforced concrete can be used in all cases for any one purpose. Within its recognized field, however, reinforcedconcrete has proven itself most useful.

CHARACTERISTICS OF REINFORCED CONCRETE

Concrete is pre-eminent in withstanding compressive stresses. Reinforced concrete, therefore, also has this quality and, in addition, reinforced concrete beams, columns, etc., have tensile strength, a characteristic which concrete alone sadly lacks. Ordinarily the reinforced concrete beam or girder is excelled by a steel member only in that the latter occupies less space. Consequently, when space is not at a premium, reinforced concrete is most excellent for beam construction.

The permanence of concrete is proven beyond a doubt by the

well-preserved old Roman aqueducts and other structures in which was used Puzzolan cement, which is ordinarily inferior to our Portland cement. Modern concrete and reinforced concrete structures are not yet old enough to shows signs of deterioration.

Reinforced concrete, when the reinforcing steel is properly protected, is practically fireproof. In many cases concrete, reinforced with an expanded metal or wire cloth, is used to fireproof steel columns. Moreover, when the reinforcing metal is properly imbedded, the surrounding concrete is an effective protection against rust or other deterioration. These considerations show that, when properly constructed, reinforced concrete is practically free from the

FIG. 2—TURBO-GENERATOR FOUNDATIONS
Reinforcement for a spread footing mat.

requirement of maintenance. This feature is especially important from an economic standpoint.

Remarkable ability to withstand vibration has also been shown. This quality must be attributed solely to the fact of the reinforcement. Furthermore, a pleasing appearance can be obtained, and that at a low cost, by the observance of the fundamental architectural requirements of proportion and simplicity.

From the foregoing it will be seen that reinforced concrete is admirably adapted as a structural material.

THEORY OF REINFORCED CONCRETE

The theories upon which reinforced concrete designs are based are manifold and often confusing. The simple beam constitutes the ordinary case, and one particular theory may be exemplified by a consideration of such a typical case. A simple beam formula is

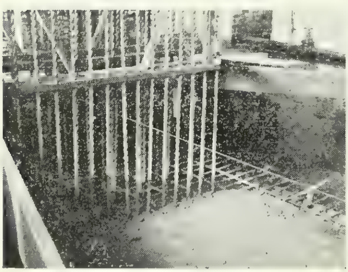
based upon assumptions of which the following are the more important: Neglect of the tensile strength of concrete; absence of initial stress in the beam; and preservation of initial plane section as a plane after strain has been applied. It is further assumed that steel reinforcement is used only to take tension and is therefore placed in the position indicated in Fig. 1. The following formula has been much used by the writer:

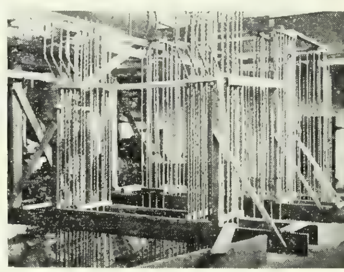
$$M_r = M_b = 0.85\ d\ p_s\ A_s$$

in which M_r = resisting moment (in.-lbs.)

M_b = bending moment (in.-lbs.)

d = effective depth of beam, i. e., distance from outermost compression fibre to center of gravity of tension reinforcement (inches).





FIGS. 3 AND 4—TURBO-GENERATOR FOUNDATIONS

Reinforcement for a large pier at steam end. Reinforcement for small piers.

p = safe unit stress in steel (lbs. tension per sq. in.)

A_s = cross-sectional area of tension steel (sq. in.)

In the derivation of the numerical portion of this formula it is assumed that the steel reinforcement composes approximately 1.00 to 1.25 percent of the cross-sectional area of the beam; that the concrete is of a first-class quality (proportions 1:2:4); that the safe tensile stress of the steel is approximately 16 000 pounds per sq. in. (based upon elastic limit); that the distance from the uppermost fiber to the line of gravity of reinforcement is approximately 93 percent of the depth of the beam (see d, Fig. 1), and that the compressive stresses are in parabolic distribution.* The stress distribution is

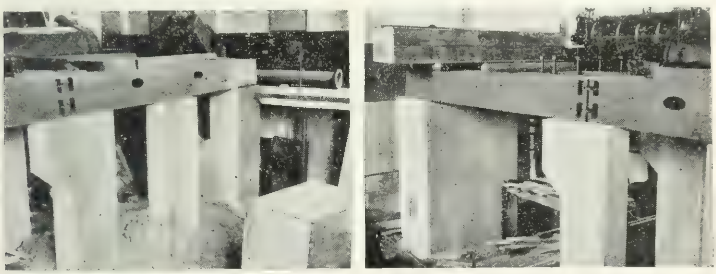
*In the case of parabolic distribution of compressive stress (axis horizontal), the average stress is two-thirds of the maximum (pc); also the centroid of compressive stress is three-eighths k below the outermost compression fiber (where k is equal to the distance from the outermost compression fiber to the neutral axis—see Fig. 1.)

shown in Fig. 1. The location of the neutral axis is assumed to be at an average ditance (under all loadings) of 0.4*d* below the outermost compression fiber; this distance being represented by *k* in Fig. 1.

The above formula agrees quite closely with test results and at the same time is eminently adapted for application in ordinary design work. It is correct as to average results, while its variations from extreme cases are usually much less in proportion than the departure of actual conditions of material and workmanship from those assumed in the design.

REQUIREMENTS OF CONSTRUCTION WORK

Reinforced concrete work of the best grade requires inspection along two lines, as to material and as to workmanship. It is neces-



FIGS. 5 AND 6—TURBO-GENERATOR FOUNDATION

A divided pier complete at electrical end. A large pier complete at steam end.

sary that the materials entering into the finished structure be as good as, or better than, those assumed in the design. Cement is an especially important constituent. However, the manufacture of Portland cement has grown to such proportions and has attained such refinements, that it seems advisable rather to emphasize the quality of the workmanship than that of the cement or other materials. When funds are limited it will often be found advisable to give more attention to inspecting the placing of the steel reinforcement and the mixing and pouring of concrete than to the testing of cement.

It is imperative also that the reinforcing steel be of the best quality, and that the sand be free from excess of dirt, that the sand and stone be used in the proper proportions, etc. Ordinarily, it is better to have the concrete, when placed, of a "sloppy" consistency. Care must be taken to bond one day's work to another and new work

to old. Often scrap reinforcement does admirably in this connection. In order that a proper "set" of the concrete may take place, favorable temperature conditions must be maintained. In freezing weather coverings must be provided, while in mid-summer or under tropical conditions the rays of the sun must be shut off. Furthermore, there should be no disturbance of the concrete during time of setting, in order that the chemical action may not be interfered with. Yet, withal, one is often pleasantly surprised at the results that are ob-

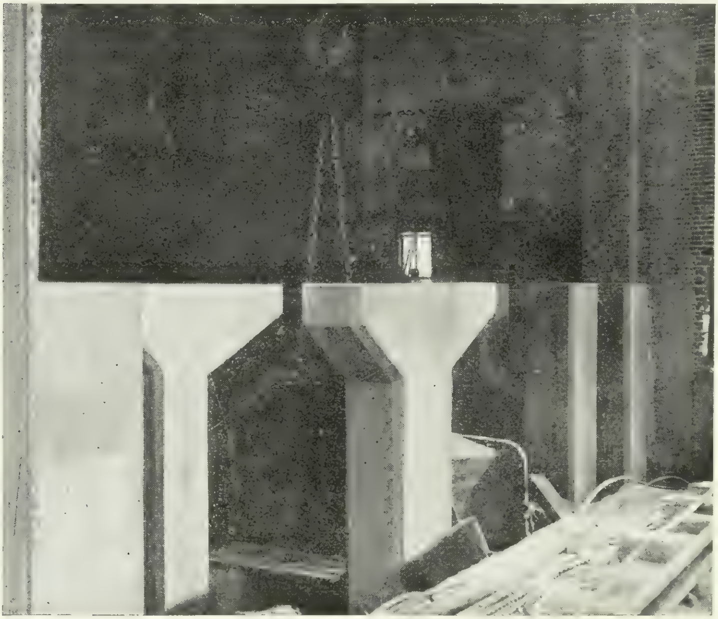


FIG. 7—TURBO-GENERATOR FOUNDATIONS
Set of cantilever piers.

tained in reinforced concrete work under the most unfavorable conditions. Ordinarily, the rare defects or weaknesses that may occur in finished work are attributable to incorrect design or poor workmanship rather than to improper materials.

APPLICATIONS IN RAILWAY AND POWER HOUSE WORK

The following examples of construction work with which the writer has been connected, illustrate the varied possibilities of reinforced concrete in large railway and lighting systems.

Power House Engine Rooms—The application of reinforced concrete in the construction of foundations for turbo-generator sets is illustrated in Figs. 2 to 7, inclusive. In these cases the ground available for footings was quite soft and the ordinary method would have been to go to rock foundation. It was found cheaper, however, to construct a reinforced concrete mat, thus distributing the load over a comparatively large area and at the same time effectively tying together the foundation piers. The use of pier instead of wall foundations allowed the utilization of a large proportion of the basement floor space and permitted arrangement for convenient operation. The spread footing mat shown in Fig. 2 was reinforced in both directions. As it was impracticable to secure rods of a sufficient total length, the rods were connected by means of a special pipe

FIGS. 8 AND 9—CONCRETE COAL BUNKER
Exterior view. Interior view.

joint. In another case the more satisfactory device of special eyebolt clamps was utilized, the rods being lapped for a proper distance.

In the construction of such foundations, the excavation having been completed, the spread footing and pier reinforcement is placed. The footing concrete is then placed, and when once set, suffices to hold the vertical pier reinforcement rigidly in position. This is shown in Figs. 3 and 4. The form work must be carefully handled in order to obtain good-looking finished work. The possibilities of careful attention to details are shown in Figs. 5 and 6.

In Fig. 7 are shown piers for another turbo-generator set, in which the arrangement of auxiliaries, condenser, etc., necessitated the carrying of the bed-plate joint on an overhanging or cantilever portion of the pier. An interesting incident, occurring after one of these turbo-generator sets was in operation, showed the ability of reinforced concrete piers to resist severe vibration. The generator had become electrically unbalanced, which soon resulted in a tre-

mendous vibration, not only in the machine itself, but extending also to the concrete piers. In fact, employees reported that a man sitting in the basement on a chair, the back of which was leaning against one of the smaller piers, was actually thrown from the chair by the vibration. This statement may be discounted ad libitum. The fact remains, however, that the most careful inspection and a subsequent service of more than two years, have given absolutely no evidence of cracking or other failure of the reinforced concrete piers underneath this set.

For engine room basement floors reinforced concrete also lends itself admirably. Pipe can be laid in trenches and covered with inexpensive reinforced concrete floor slabs, thus leaving them easily

FIG. 10—COMBINATION FLOOD PROTECTION AND INTAKE SYSTEM

accessible. In some cases it has been found advisable to place the suction and discharge pipes of the circulating water systems for condensing in reinforced concrete trenches or tunnels. In this way the piping is always accessible for re-calking or replacement.

Boiler Houses—In the boiler room, as in the engine room, reinforced concrete has innumerable applications. The coal bunkers shown in Figs. 8 and 9 were built upon a supporting structural steel framework, but with a body of reinforced concrete. Thus the greater part of the steel is protected from the corrosive action of the coal and the structure given a much longer life than with the simple steel construction. A reinforced coal hopper, to receive coal from bottom dump cars has proven most satisfactory. The coal wears the

concrete as smooth as sheet steel, while there is no question about its durability. The reinforcement of this hopper consists principally of expanded metal, the concrete in the sloping sides of the hopper being placed with under, but no upper forms.

At the same power house the writer constructed a reinforced concrete smoke flue which was undoubtedly the first of its kind. The interior dimensions of the breeching are, approximately, 9 by 11 feet, the walls and roof being only five inches thick, reinforced with expanded metal. The whole concrete structure was built upon the

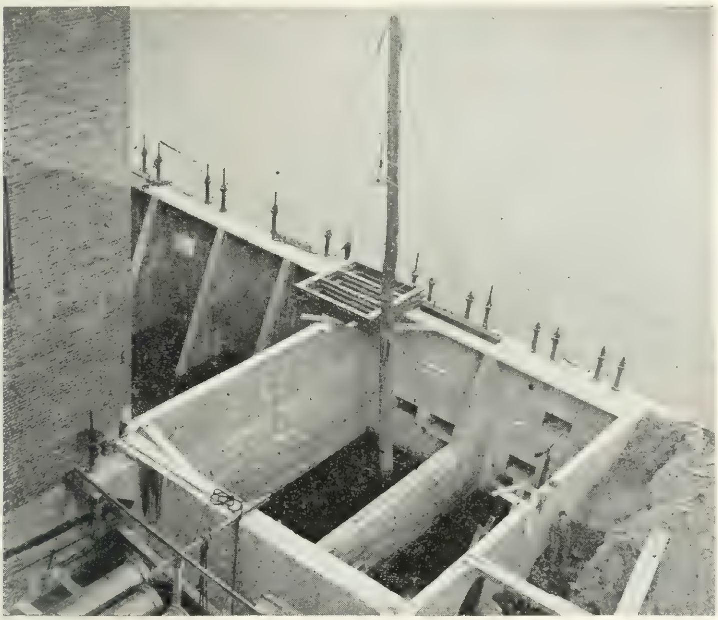


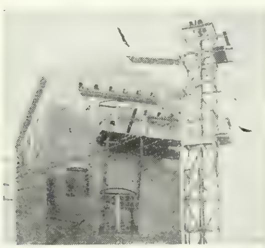
FIG. 11—INTAKE SYSTEM FOR POWER HOUSE
Employing reinforced concrete. View from above.

boiler setting, resting upon an intervening layer of three-ply tar paper greased on both sides. Frequent expansion joints were used. The section of the flue first constructed is not entirely free from cracks but, due to a change in the position of the reinforcement, a portion about 85 feet long built later is practically free from such defects. Both old and new sections of the reinforced concrete breeching have proven superior to the old style of steel breeching.

Other Power Station Structures—A combination of protection and retaining wall and intake system for a large power house is

shown in Fig. 10. This structure has served to provide immunity against damage by floods and against interruptions by clogging of condenser tubes due to the materials carried by the stream during high water. Practically all of the construction is of reinforced concrete. The protection and retaining wall has a "heel" which extends back under the fill, causing the fill to support the 22-foot wall.

The illustration shows the arrangement of intake screens and gates at various heights, the purpose being to allow of the taking of the water from the upper and purer portion of the stream during flood conditions. The division into cells for the intakes of the various condenser units is shown in Fig. 11. The division walls were so designed as to permit the pumping out of the water in any cell under ordinary conditions. The cells are inter-connected by



FIGS. 12 AND 13—WOODEN ROOF OF TRANSFORMER HOUSE REPLACED BY REINFORCED CONCRETE ROOF

Showing method of carrying on the work.

Completed roof showing concrete gutters.

gates, while the intermediate wall parallel to the river wall is provided with fine screens which effectively retain cinders, wood fibre, etc., which may have passed through the coarser gratings in the outer wall.

A transformer house and high tension building, the wooden roof of which is in the process of replacement by a reinforced concrete roof, is shown in Fig. 12. It was essential that this work be done most carefully on account of the danger, both to life and operation, in view of the fact that the room directly underneath the roof was filled with air-break high-tension switches.

All of the work was done from the outside by means of the elevator shown in the illustration. The old wooden roof was strengthened by the use of props underneath and served as form work for the new roof. Before concrete was placed the old roof was covered with tar paper, the seams of which were in turn tarred

in order to minimize the leakage to the room below. This piece work was successfully accomplished with the result as shown in Fig. 13.

Sub-Station Construction—In sub-station work, also, many difficult structural problems may be solved by the use of reinforced concrete. It finds application here in foundations, walls, roofs, floors, galleries, transformer cells, switchboards, etc. In the case of one sub-station which was constructed against the side of a hill, the building was so designed that the transformers were placed in the basement, thus saving a considerable amount of space. Reinforced concrete curtain walls were used to separate the transformers, while underground concrete ducts, communicating with the outside air, afforded ample ventilation. An opening may be made in the main floor of the building by removing several reinforced concrete slabs, and in this way the transformers can be lifted from the basement through the floor and thence shifted to a car for shipment, or dismantled for repair.

FIG. 14—SUB-STATION CONSTRUCTION

A reinforced concrete gallery.

In the same station, a reinforced concrete pit was constructed directly back of the switchboard in which various apparatus was placed. It also provides convenient means for carrying cables and wiring from switchboard to machine and transformers. A series of fiber conduits was imbedded in the floor so as to connect each machine with the switchboard. Essentially the floor consists of a series of reinforced concrete beams with intervening concrete covered conduits. Such arrangement requires careful planning of the sub-station installation, but is found to be highly profitable as regards simplicity and reliability of operation.

Reinforced concrete galleries may be used to economize floor space. Such galleries, as shown in Fig. 14, may be used for carrying high-tension switches, choke coils, static arresters, etc. In this particular case the gallery is supported by rods from the roof. The reinforced concrete floor is but four inches in thickness and is sufficiently strong to carry a number of repair men in addition to the apparatus.

A reinforced concrete roof under construction is shown in Fig.

15. It will be noticed that the reinforcement, consisting in this case, of electrically welded wire cloth, is laid in wave fashion. The object is to keep the reinforcement always in the tension fiber between beams and in the upper fiber directly over the beams (providing the roof be a continuous slab over the beams). Often it is possible to

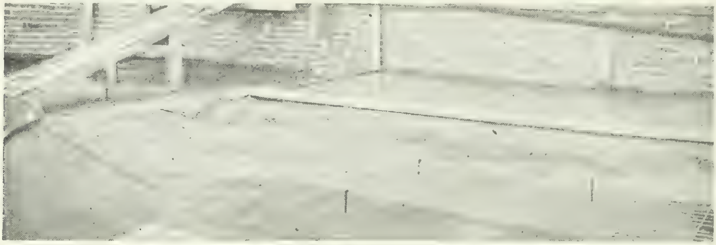
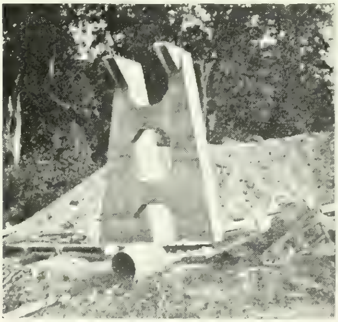
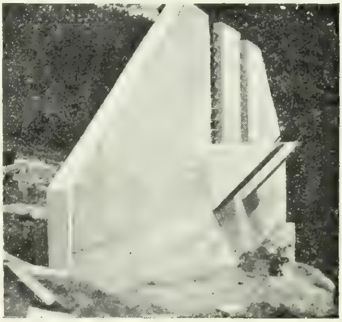


FIG. 15—SUB-STATION CONSTRUCTION
A reinforced concrete roof under construction.

construct a roof without beams and in such cases, twisted or other steel rods are substituted for wire cloth or expanded metal. The illustration shows how bolts may be imbedded in the concrete roof so





FIGS. 16 AND 17—REINFORCED CONCRETE BRIDGE CONSTRUCTION
A skeleton abutment. A wing wall abutment.

as to project from the ceiling below in order that insulators or minor apparatus may later be attached thereto.

*Railway Bridges**—The concrete girder bridge is a development

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*An article by Mr. Scheidenhelm under the title, "Long Span Reinforced-Concrete Girder Bridge," dealing with the design and construction of the bridges described herewith, more particularly from the civil engineering standpoint, appears in the *Engineering News* for Jan. 27, '10, p. 85. Results of interesting electrolysis tests on reinforced concrete are also briefly outlined in this article.

made possible by the addition of steel reinforcement. Figs. 16 to 22, inclusive, indicate in outline what may be accomplished along this

FIG. 18—REINFORCED CONCRETE BRIDGE
Falsework and construction plant.

line. The two bridges shown in the illustrations were constructed only after thorough comparison had been made with standard steel designs for the same sites. It was found that the total costs of

FIG. 19—REINFORCED CONCRETE BRIDGE
Reinforcement in place for large girders and deck.

reinforced concrete and of steel are practically equal, the reinforced concrete structure, however, having the advantage of stabil-

ity and a minimum of maintenance. The bridges in question are entirely of reinforced concrete from footing to girder. Footings are of the spread type, several of them resting upon gravel; whereas, with the ordinary pier it is necessary to go to rock for foundation.

Two types of abutment were used, as shown in Figs. 16 and 17, respectively. The former illustration presents a new departure in the buried abutment. This so-called "skeleton" abutment has openings which allow the earth fill around the abutment to spill through and in this way relieve the earth pressure, which has been the ruin of many an expensive structure. The rails are carried upon girders connected by a ten-inch deck. The cross-section diagram, Fig. 20, shows the arrangement of the reinforcement. In the longer spans the girders are further braced by web stiffeners at about 20 feet spacing (see Fig. 21). Each girder is carried up above the deck and above the rails so as to form a guard rail, the inner edge of this guard rail being protected by an imbedded bulb beam. The rails are imbedded directly in the concrete deck, a form of construction which is somewhat novel, but which has worked out admirably in design and construction Owing to the extreme haste necessary in the construction of these bridges, it was impossible to obtain standard reinforcing bars in time for use in the footings and abutments. For these, second-hand mine haulage cable was used, which fulfilled the requirements very nicely. It was necessary, of course, to carefully inspect this material and to utilize it only with an ample factor of safety. The reinforcement of the piers and girders consists of twisted square steel rods of high elastic limit steel, in sizes ranging from ½ to 1¼ inches, as shown in Figs. 19 and 20.

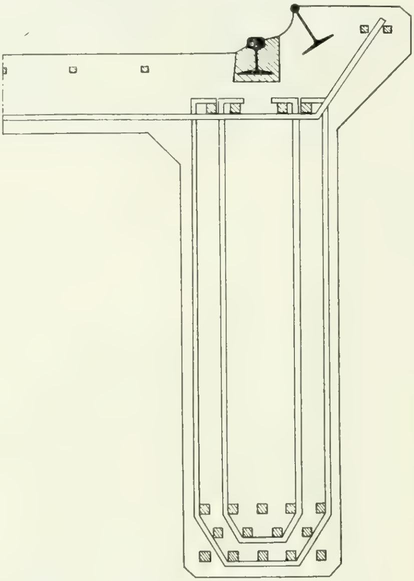

FIG. 20—DIAGRAMATIC CROSS-SECTION OF 75 FT. GIRDER

A distinguishing feature of the bridges is the length of span. Fig. 22 shows a 75-foot span which is nearly eight feet longer than

any other reinforced concrete girder span for railway loading that has yet been built. The results of this particular construction indicate that the limit of span length in girder work has not yet been reached. The matter of economy, of course, is of extreme importance in such instances and must be determined for each particular case. Ordinarily, for such long spans an arch, either plain or reinforced, would be more economical than girder construction.

The piers and abutments of these bridges were built complete before work was begun on the girders. The reinforcement of both

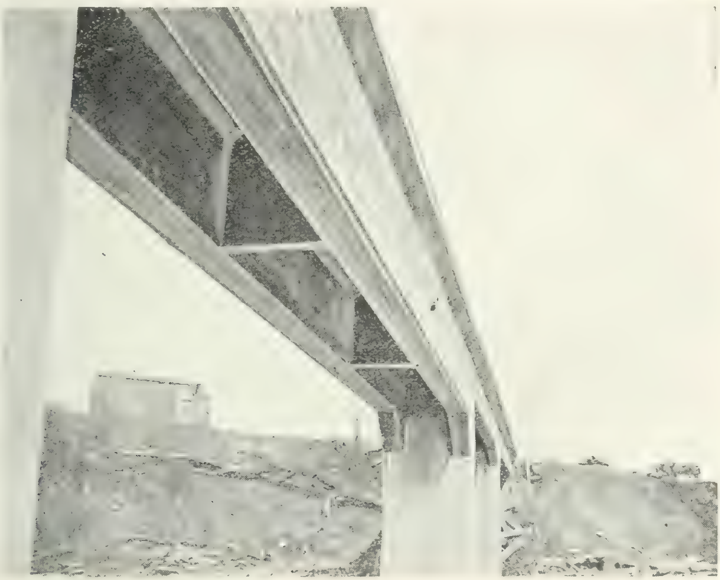

FIG. 21—REINFORCED CONCRETE BRIDGE
View underneath 67 ft. span of completed bridge showing stiffening webs.

piers and abutments was allowed to extend a sufficient amount above their tops in order to properly tie the girders to them. False work and form work for all of the girders of the bridge were then put in place as shown in Fig. 18. The girder concrete was then poured in a continuous operation, occupying about thirty-six hours. In this way perfect bond, maximum strength and continuity over piers were insured. Tests of these bridges with overloads as much as 30 percent greater than the design loads failed to show deflections of even 5/16 of an inch. On the basis of deflection the factor of

safety in some of the girders would seem to be as high as 16. It is practically certain, however, that in these cases failure would occur due to other causes than bending moment stresses.

In operation these bridges have proven to be free from excessive jar or vibration. For instance, the noise of vibration, due to a car passing over a bridge of this type, is considerably less than that of steel bridges, yet the elasticity of the structure is evident, being easily detected by the touch of the hand.

Transmission Line Towers—A notable application of reinforced concrete in connection with transmission line work is shown in Figs.

FIG. 22—COMPLETED REINFORCED CONCRETE BRIDGE

A 75 ft. span under test load. This is the largest reinforced concrete girder span for railway loading in the world.

23 and 24. The illustrations show a main tower, which is 120 feet in height above the foundation. This tower carries only the weight of the cables and the transverse wind load against cables and tower. The strain or pull of the cables resulting from a 1 014-foot span is taken up by a reinforced concrete anchorage tower of lesser height. Both towers are set upon spread footings, that of the main tower being 30 feet square. The comparatively poor soil made it necessary to reduce the footing pressure under maximum wind load to approximately 1 400 pounds per square foot. These towers built in 1906, have shown no movement and no deterioration. No expenditures have been made for maintenance.*

CONCLUSION

The writer's experience in reinforced concrete design and construction leads him to believe that the application of reinforced concrete is still far from its maximum development. It must be insisted, however, that the use of reinforced concrete requires intelligent consideration, as much regarding its limitations as of its advantages. Comparison with other materials as regards adaptability and economy should always be made. Uniformity, too, is sometimes an important consideration. For bric-a-brac work and small di-

FIGS. 23 AND 24—REINFORCED CONCRETE TRANSMISSION TOWER

A 120 ft. tower under construction.

Completed transmission line tower.

mensions concrete construction is costly, often to the point of being prohibitive. Nevertheless, the accomplishments in the use of reinforced concrete for artistic and decorative work often border on the marvelous. For the heavier classes of work reinforced concrete must now be recognized and ranked as of equal importance with other structural materials.

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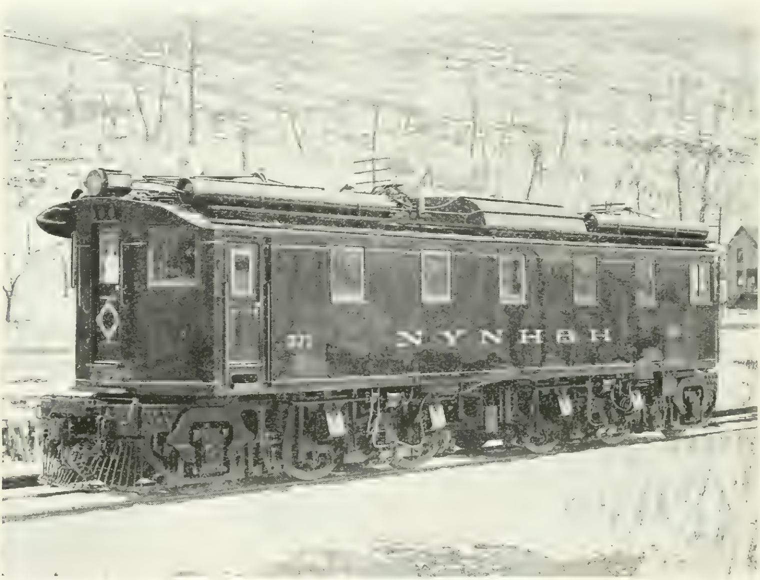
*For more extended description of these towers see the *Engineering News*, May 2, 1907, p. 476.

NEW ELECTRIC LOCOMOTIVES FOR THE NEW HAVEN RAILROAD

N. W. STORER

A NEW type of electric locomotive has just been completed and tested with remarkable success on the Interworks Railway of the Electric Company at East Pittsburg. The tests were made in the presence of Messrs. E. H. McHenry, vice president, and W. S. Murray, electrical engineer of the New York, New Haven & Hartford Railroad.

The mechanical design of the locomotive is the result of the joint efforts of the engineers of the Baldwin Locomotive



GENERAL VIEW OF NEW TYPE OF NEW HAVEN RAILROAD LOCOMOTIVE
Equipped for operation on both 25 cycle single-phase alternating current and direct current.

Works and the New Haven Railroad Company. The entire electrical equipment, including the spring drive of the large motors, is the design of the Electric Company.

The design of the locomotive is unique. It is of the "articulated" truck type, having a cab 44 feet in length, resting on two trucks. These trucks are coupled together and are equipped with standard Westinghouse friction draft gear attached to M.C.B.

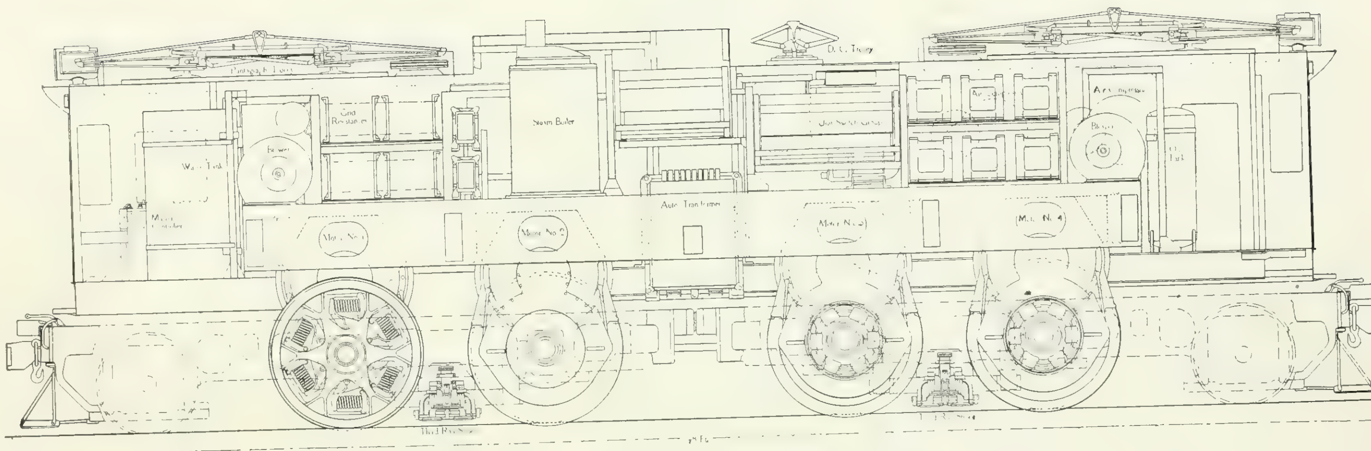
couplings at the ends of the locomotive. Each truck is of the radial swing bolster side bearing type and contains two pairs of drivers. The drive wheels are 63 inches in diameter and the pony truck wheels are 42 inches in diameter.

The total weight of the locomotive is 150 tons. The weight of the cab is carried on friction plates at the ends of the trucks, instead of being carried on the truck center pins. The weight is applied through springs which have a considerable latitude for motion to allow for variations in the track without changing materially the distribution of weight on the ends of the truck. At the same time the friction of these plates exercises a steadying effect on the locomotive, and effectually prevents any periodic vibration or "nosing."

TRUCKS OF NEW HAVEN LOCOMOTIVE WITH MOTORS IN POSITION

There are four motors, each motor being mounted rigidly on the truck frame and directly above a quill surrounding the driving axle, to which it is geared. The quill drives the wheels through a system of helical springs. This arrangement allows a maximum motion of 1½ inch above or below the center of the axle. Twin gears are employed on each motor.

The rigid wheel base of the locomotive is 7 feet for each truck, so that the locomotive is extremely flexible and easy on the track at curves and special work. The present weight of 150 tons will undoubtedly be much reduced on future locomotives of this type. It may be noted in this connection that, compared with the locomotives in operation on the New Haven Railroad at present, the new locomotive has about twice the capacity for hauling trains. This is ob-



SIDE ELEVATION OF NEW HAVEN LOCOMOTIVE SHOWING ARRANGEMENT OF MAIN APPARATUS AND PARTS

Each motor is connected to its respective set of drive wheels through twin spur gears, quill and helical springs. The latter are shown in connection with motor No. 1. The master control apparatus, meters, air brake valve, sanding foot lever, etc., are in duplicate at either end of the cab, and jumper connections are provided for multiple operation of locomotives from a single master controller. To economize space the main air reservoirs are mounted on the roof of the cab, at either side of the alternating-current pantagraph trolleys. There are two distinct trucks on which the single cab is carried.

tained by the use of geared motors operating at somewhat higher speeds than the gearless motors in the old type of locomotives. It was feared that the gears might prove to be noisy, but they are built with springs between the gear center and rim, so that they are extremely flexible, and all shock which ordinarily produces noise is absorbed by the springs and the locomotive operates with practically no perceptible noise from this source.

On account of the motors being above the axles, they project into the cab and the floor above them is raised in the same way as in the Pennsylvania 10 003 type of locomotive. This raised floor extends the full length of the cab, except for a space at either end provided for the motorman. This method of mounting the motors, rigidly on the truck frame above the axles and allowing them to swing freely with the frame, gives a high center of gravity, which is recognized as being very desirable for electric locomotives and makes, together with the mechanical features in its design, one of the easiest riding electric locomotives ever built.

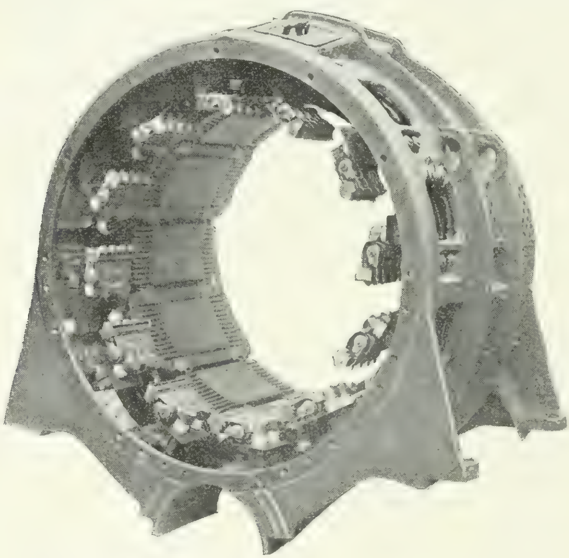
The locomotive is provided with two 11 000 volt pantagraph trolleys, mounted on the roof, for collecting the single-phase current. Either of these can be raised or lowered at the will of the engineer. Because of the operation of the New Haven and the New York Central trains on a common right of way at their New York terminal with direct-current third rail power supply, it is necessary that the New Haven locomotives be equipped for operation on both alternating and direct current. The direct-current voltage is from 600 to 700 volts, the current being collected from the third rail by means of four sets of sliding shoes which, when not in use, can be folded up close to the frame of the locomotive. At crossings, etc., in the direct-current zone, an overhead conductor is substituted for the third rail, for which a collector, consisting of a small pantagraph trolley, is provided, likewise controlled from either end of the cab by the engineer.

The control of the motors is accomplished by means of electro-pneumatically operated switches. With this form of control two or more locomotives may be operated together from one master controller.

The equipment in the cab is complicated by the provision for operation on direct as well as alternating current, and by the addition of a steam boiler with storage tanks for oil and water for heating the passenger trains. It is not expected that these features will be necessary for locomotives used for freight work only. The motors

are connected two in series for operation on direct-current, and the regular series parallel control is used. When running on alternating current, all motors are connected in parallel. In either case, any motor may be cut out, leaving the other three in service.

The change-over from alternating to direct-current and vice versa, is accomplished by means of a set of double-throw switches on a switchboard located near the center of the cab. The switches are thrown up when on direct and down when on alternating current, thus making the operation very simple. When in the direct-current zone, the starting current is limited by resistance in the usual way. On alternating current, the speed is regulated entirely by varying the



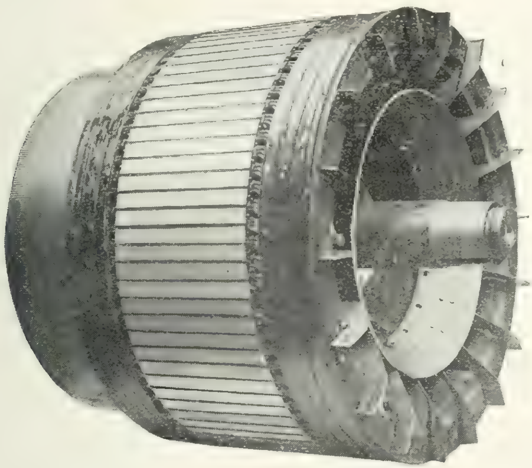
VIEW OF STATOR SHOWING WINDING AND BRUSH RIGGING
New Haven Locomotive.

voltage applied to the motors, by means of taps on the transformer and switches used in connection with a system of preventive coils. There are 13 running voltages on the controller, so that the speed control is extremely flexible and any speed can be used up to the maximum, with any tractive effort.

The motors are of the same general design as those in use on the present New Haven locomotives, the main differences being in the mechanical details and general arrangement. A single transformer is used, located in the middle of the cab.

The locomotive specifications require that it shall be able to haul a 1 500-ton freight train at a speed of 35 miles per hour on

level track, where the train resistance does not exceed six pounds per ton. It is also required that it be capable of hauling the heaviest New Haven passenger train, weighing 800 tons, at a speed of 45 miles per hour. In other words, the equipment is designed to haul an 800-ton passenger train in "limited" service between the Grand Central Station, New York City, and New Haven, a distance of 73 miles, making no intermediate stops, in one hour and 50 minutes. Likewise, in "express" service, in which the principal stops are made, the running time specified for an 800-ton train is two hours and 12 minutes, allowing a total of five minutes for stops. The specified running time for 350-ton trains in local passenger service, making all stops the average of which is not to exceed 45 seconds, is two hours and 45 minutes.



ARMATURE OF NEW HAVEN LOCOMOTIVE

During the test referred to above, the locomotive started and accelerated a 2 100-ton freight train, both on level track and on an up-grade of 0.3 percent on a three degree curve. A train corresponding to the 800-ton passenger train was accelerated at a rate of about 0.4 miles per hour per second, thus quickly reaching the required speed. Each motor has a one-hour rating of about 375 horsepower and a continuous rating of approximately 310 horsepower. It is thus quite evident that the full capacity covered by the locomotive specifications has been reached with a fair margin. There will therefore be no question as to the ability of the locomotive to perform the service requirements as far as the capacity of the equipment is concerned.

6 000 HORSE-POWER HYDRAULIC ABSORPTION DYNAMOMETER

FOR TESTING THE MELVILLE AND MACALPINE SPUR WHEEL REDUCTION GEAR

IN the article by Mr. George Westinghouse describing the Melville and Macalpine reduction gear, in the January issue of the JOURNAL, mention was made of the means of measuring the power transmitted by the gears by a dynamometer of novel design. As it was necessary to devise some means of measuring a continuous output of 6 000 horse-power, it is evident that some means very much out of the ordinary was demanded. One of the methods sug-

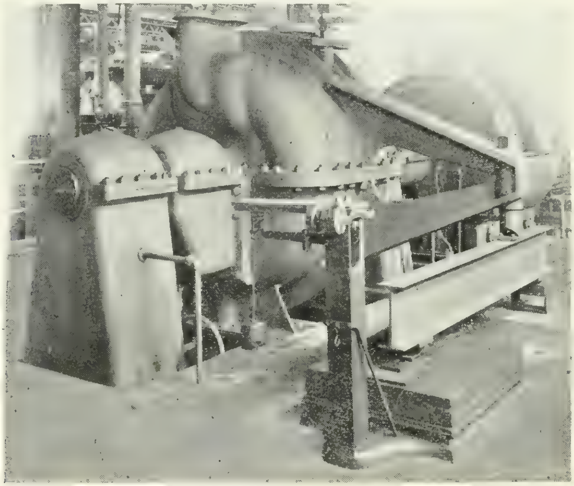


FIG. 1—GENERAL VIEW OF 6 000 HP HYDRAULIC ABSORPTION DYNAMOMETER
Showing method of weighing load.

gested was the use of an electric generator, with a water resistance for adjusting and maintaining the load. Such a method would have been expensive and the water resistance would have been cumbersome. Moreover to many, indications of output as shown by electric meters are not quite as convincing as a direct comparison with the familiar force of gravity as obtained by the use of the ordinary band or Prony friction brake, by which the power may easily be determined by noting the pressure on the scale and the speed of the

shaft. The common form of Prony brake was, of course, entirely out of the question as the difficulties involved in the construction of such a brake, the dissipation of the heat energy generated and the maintenance of the necessary tension in the brake band to produce the desired horse-power output, would be practically insurmountable. This is very evident when it is considered that in the friction brake the energy absorbed is transformed into heat and the problem of dissipating the heat developed by the absorption of 6 000 horse-power in mechanical energy would be a very serious one. The magnitude of this problem will be better comprehended when one recalls that the quantity of heat generated by the absorption of one horse-power is 2 545 B.t.u. per hour. Thus, for 6 000 horse-power it would be necessary to dissipate 15 270 000 B.t.u. This amount of heat is practicably the amount which would be generated in a furnace burning coal continuously at the rate of 1 200 pounds per hour.

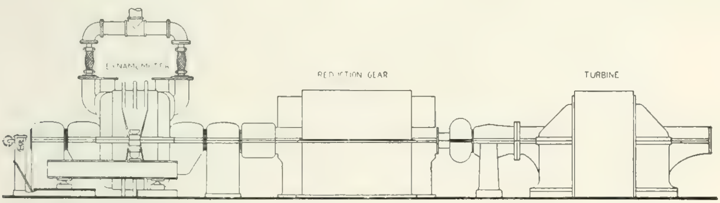


FIG. 2—ARRANGEMENT OF TURBINE, REDUCTION GEAR AND DYNAMOMETER

As it was hoped that the loss in the reduction gear would be very small it was necessary that the means of measuring the losses be correspondingly accurate. For a number of years a form of hydraulic brake has been used by the Westinghouse Machine Company for measuring the power developed by their steam turbines on shop tests. This form of brake consists of a rotor mounted on a shaft coupled to the turbine shaft, and rotating within a closed casing supported on journals through which the rotor shaft passes. The casing is prevented from turning by means of a radial arm bearing against a vertical strut, the lower end of which rests on an ordinary platform scale. Within the casing is a quantity of water, which quantity may be maintained constant at any desired amount by means of inlet and outlet pipes with adjustable controlling valves. The rotor has a series of vanes or teeth on its periphery which tend to impart a rotary motion to the water contained in the casing. The inner surface of the casing is provided with vanes or teeth which resist this tendency, and the result is a

powerful braking action, the intensity of which can be regulated by the quantity of water in the casing. The resistance which the casing must offer to prevent its being rotated by the water striking its inwardly projecting vanes at high velocity is measured by the pressure exerted on the platform scale by the strut under the radius arm, and from this pressure, the effective length of the radius arm, and the number of revolutions per minute, the power is calculated in identically the same manner as in the case of an ordinary Prony or band

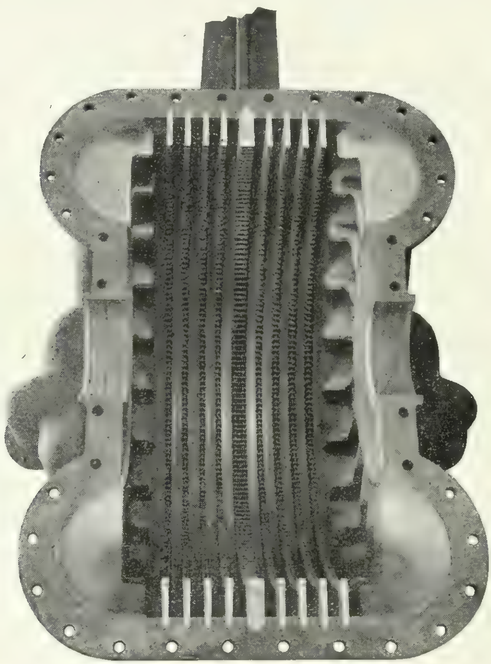


FIG. 3—INTERIOR VIEW OF UPPER HALF OF CASING OF HYDRAULIC ABSORPTION DYNAMOMETER

brake. As a matter of course, the temperature of the water is quickly raised to the boiling point, and a considerable portion of it evaporates, and in the form of steam easily carries off the enormous quantities of heat generated. The amount of fresh water admitted to compensate for the quantity lost by evaporation and through the overflow pipes, is constantly adjusted by the attendant in such a way as to keep the scale at all times in perfect balance.

The successful brakes constructed on this principle had all been designed for high speeds, ranging from 750 revolutions

per minute for the largest, up to 4 000 or more for the smallest sizes. In order to adapt the same principle to a brake that should have the requisite capacity and stability at the lower speeds of the driven shaft of the reduction gear (in this case 300 r.p.m.), it was necessary to prepare a radically new design. The brake used on these tests was designed by Mr. R. N. Ehrhart. A general view of the completed brake and the method of weighing the load is given in Fig. 1. The relative arrangement of the turbine, reduction gear and dynamometer is shown by Fig. 2. On account of the heavy pressures to be dealt with, the force exerted by the

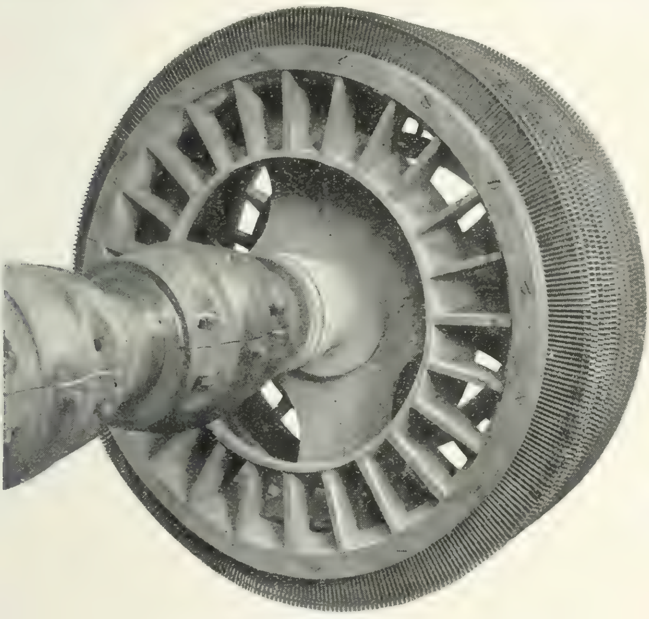


FIG. 4—ROTOR OF HYDRAULIC ABSORPTION DYNAMOMETER
Side view showing water inlet ports and blades.

radius arm is not exerted directly on the platform of the scale, but is transmitted through a knife edge bearing to an I-beam, one end of which rests on a solid foundation and the other on the platform of the scale. The I-beam rests on knife edge supports at either end, and forms a lever of such proportions that only one-fourth of the total stress comes on the scale. At the top of the dynamometer are flexible hose connections for admitting water to the interior of the casing.

The stationary vanes, which resist the impulse imparted to the water by the rotor, are inserted and supported in precisely the same

manner as the blades in the cylinder of a steam turbine. An interior view of the upper half of the casing is given in Fig. 3.

The rotor is provided with regular steam turbine blading sections, the rows on one side of the center being what is called "right hand sections," and on the opposite side of "left hand section." The water enters the top half of the casing through ports on either side which register with the passages in the side of the rotor, shown in Fig. 4 just inside the rim. Through these passages the water is carried to the middle of the rim of the rotor and discharged through the ports shown in Fig. 5 between the innermost rows of blades.

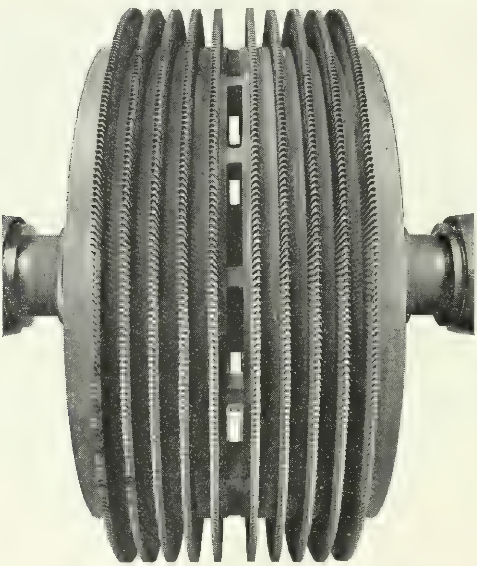


FIG. 5—ROTOR OF HYDRAULIC ABSORPTION DYNAMOMETER

View from above showing water inlet ports and blades.

By the aid of the developed cross-section through the blades, Fig. 6, the action that next takes place may easily be understood. The moving blades are shown in solid and the stationary blades in cross-lined section.

The water emerges with a whirling motion from the port *A*, and immediately meets the broad central row of stationary vanes which check its angular velocity. It escapes to the right and left from the passages between the central row of stationary vanes and is picked up by the first rows of moving blades on either side. These moving

blades again impart a high angular velocity to the water, and by reason of the curvature of their section project it into the adjacent rows of stationary vanes, where the velocity is again checked. This action

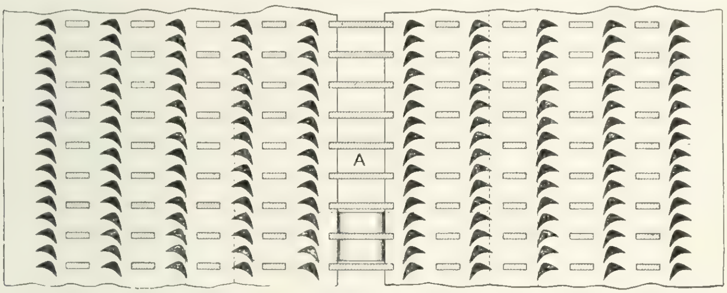


FIG. 6—DEVELOPED CROSS-SECTION THROUGH BLADES

The movable blades are designated by the solid sections and the stationary blades by the cross-lined sections. The action is similar to that in a double-flow steam turbine. The water inlet ports are located at *A*.

is repeated as the water passes through the successive rows of moving and stationary blades, until it reaches the outermost rows of moving blades. From these last rows of moving blades the water is projected into circumferential passages of semi-circular cross-section in either end of the casing.

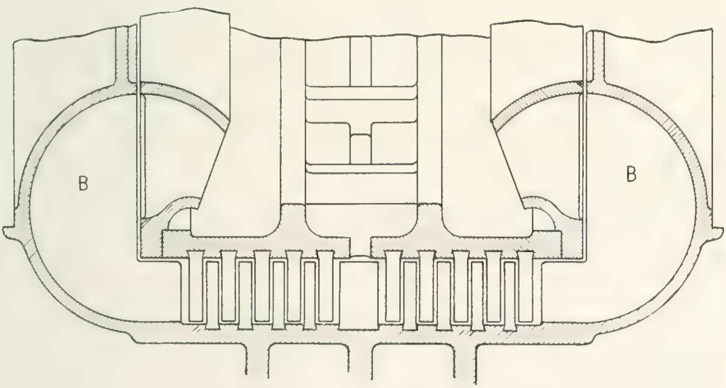


FIG. 7—PARTIAL CROSS-SECTION THROUGH ROTOR AND CASING

The water and steam, after passing the stationary and movable sets of blades, are received in the passages *BB*.

These passages are shown at *B* in Fig. 7, a partial cross-sectional view through the rotor and casing. At intervals in these circumferential passages are baffles to again check the angular velocity of the water. These baffles may be seen in Fig. 3. The passages in

the casing re-direct the water into the rotor, or at least so much of it as has not been already evaporated, and the entire cycle of operation is repeated indefinitely.

A section through the assembled dynamometer is shown in Fig. 8. The passages through which the water enters are indicated by the letters C and C′. D and D′ are vents for the escape of the steam generated by the transformation of the mechanical energy into heat. It is not practicable to carry off all of the heat by evaporation alone, as the generation of 15 000 pounds of steam per hour in the casing would cause such a violent boiling as to interfere with the stability

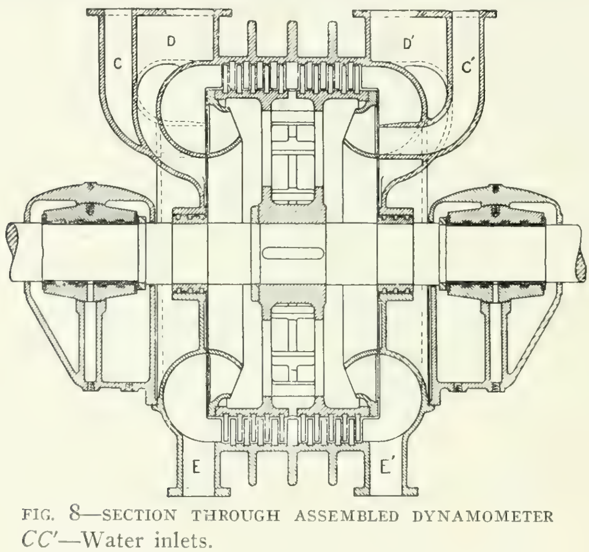


FIG. 8—SECTION THROUGH ASSEMBLED DYNAMOMETER
CC′—Water inlets.
DD′—Vents for escape of steam.
EE′—Outlet ports for discharge of boiling water.

of the braking action. Consequently the quantity of water admitted into the casing is considerably in excess of the quantity evaporated, and the surplus is discharged at boiling temperature through the passages *E* and *E.′*

This dynamometer measures the output of the reduction gear with the utmost precision and, notwithstanding that it was an entirely new creation, has operated in the most gratifying manner as regards steadiness, sensitiveness, and capacity, and in general has creditably upheld its part in what is perhaps the most extensive laboratory experiment that has ever been undertaken and carried out by strictly private enterprise.

INDUSTRIAL ENGINEERING BY THE CENTRAL STATION*

JOHN C. PARKER

Mechanical and Electrical Engineer, Rochester Railway and Light Co.

ABOUT two and one-half years ago the Rochester Railway and Light Company, recognizing that in the extension of its business and in the securing of the more difficult classes of industrial load further technical skill was needed than could be supplied by their commercial forces, decided to secure the services of some good technically educated men to assist in the work of securing additional power users. The writer was at that time doing engineering work for the company in connection with the introduction of Niagara power, and on his recommendation Mr. A. M. Dudley, at present section engineer with the Westinghouse Electric & Mfg. Company, was brought to Rochester. Although Mr. Dudley stayed only four days, and in that time undertook only one project, the results thereof amply justified the institution of the work.

A customer doing a foundry business had complained of high bills, and on Mr. Dudley's investigation it was found that by a reduction of one-half inch in the diameter of the pulley on the motor driving the foundry blower, the pressure could be reduced from 27 to 20 inches, thereby obviating ten inches of throttle, and effecting a saving for the customer of $80 to $100 per month. The results were so satisfactory that when Mr. Dudley was drawn back to Pittsburg to take charge of his present work, negotiations were opened with Mr. H. W. Peck,† then of Baltimore, and formerly of the Electric Company's engineering department. Mr. Peck came about two years ago, and is at the present time the principal assistant in the engineering department in charge of industrial investigations. Of the 20 employees in the engineering department, 12 are at the present time doing industrial engineering work, and we are constantly on the lookout for new men of ability and resource.

THE LINE OF ATTACK

The line of attack in this work is, we believe, novel and offers

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*Revised by the author from a paper presented before The Electric Club, December 2, 1909.

†Mr. Peck is the author of an article on "The Application of Electric Motors," which appeared in the JOURNAL for February, 1909, p. 83.

many elements of interest. The work is certainly as diversified as anything short of consultation practice, and it is probably no more specialized than the latter. When a new customer is to be secured, or when an old customer is in imminent danger of leaving us, or is for any reason dissatisfied with his costs, a man from the engineering department investigates his plant conditions as a whole, and reports in language readily understood by a layman just what we can do to make the service better or cheaper. This, in many cases, involves a study of conditions absolutely non-electrical. In general, the studies involve going into the customers' processes, sequence of operations, mechanical conditions, etc., and the pointing out of methods whereby he can improve these, very often with a reduction in the annual energy consumption, it being our belief that we should sell utility rather than power, i. e., that we should endeavor to make each kilowatt-hour sold produce the maximum value to the customer, even though the number of electrical units disposed of is thereby reduced.

A TYPICAL EXAMPLE

This can best be illustrated by taking a case in point and showing how in the sequel the central station company benefits by a broad and generous attitude in the matter.

In the pasteurization of milk it is the practice to heat the milk in a water bath, which is in turn steam heated, the milk being raised to a temperature of 160 degrees F. and then rapidly cooled by a refrigerating machine to the temperature of the storage room, which is approximately 40 degrees F. One of our engineers had succeeded in converting a local dairy to electric drive, replacing the turbine drive of the cream separator by a motor and, among other things, equipping the ammonia compressor of the refrigerating plant with a variable-speed, direct-current motor. The object in the variable speed was to enable the customer to run for long hours at reduced power rate, thereby enabling him to reap the fullest advantage from a good load-factor, as our rates are based on the customer's load-factor. After securing the installation, the engineer went further and found a type of pasteurizer in which milk, previously heated to 160 degrees, subsequently, during the cooling process, gave up heat to the incoming milk by means of a countercurrent interchanger, the steam being used to supply only the necessary temperature gradient to operate the interchanger and make up losses to the atmosphere.

With this type of pasteurizer the burden on the refrigerating plant is greatly reduced, and by the further substitution of water cooling between the lowest temperature obtainable by the interchanger and the temperature of the milk at which the brine must be used, the load on the refrigerating machine is still further reduced. This would, in the first case, permit the use of slower speed and hence less power on the ammonia compressor of the refrigerating plant. Again, by an improvement in the insulation of the walls of the storage room a still further economy is obtainable. Now it so happens that ice must be used in the delivery wagons, and as the refrigerating machine capacity is already installed in the plant, the only cost for ice manufacture is that of the power and water required. It was thus advantageous for the customer to install a small brine tank with cans which can be filled with tap water. The ice so produced is, of course, opaque, looking like so much marble, but is perfectly good, aside from its appearance, and could, if desired, be used for table purposes, as the Rochester water supply is absolutely pure. The customer can quickly load up his ice machine and produce ice at a cost of 80 cents per ton, as against a purchase price of $5 or $6 per ton.

Now what we have done here has been, not to sell less power to the customer, nor to sell at a lower rate, but to increase the value to him of the service rendered by our company, with the result that he cannot afford in the future to do other than deal with us.

The engineering work involved in this project has been but briefly sketched. It will probably be of interest to hear how much further we have had to go with this undertaking. It happens that the manufacturer of the pasteurizer is not himself familiar with the engineering design of his product, being merely an inventor; and it further happens that by a duplication of standard parts in his apparatus more or less advantage can be taken of the excellent features in his design. We have, therefore, made studies and recommendations based on the economic amount of the interchanger surface; the economic amount of the water cooling surface, and the economic amount of the brine cooling surface to be used. These studies involve the principle that where the installation of any one item in the piece of apparatus involves only an increase of depreciation, interest and tax charge, plus an increase in operating cost, which is more than offset by the annual value of other investment set free for other more useful purposes, plus a saving in operating cost, this change is desirable. When the one just equals the other, it becomes a matter of indifference as to whether the

change is made or not. So in the present case, doubling the interchanger surface makes it possible to halve the difference in temperature between the milk passing into the pasteurizer and out of it. This makes it possible to reduce the steam consumption for heating the milk in the pasteurizer and to reduce the amount of water and brine cooling, and thereby to set free a certain amount of refrigerating machine capacity for more useful purposes, incidentally saving in power. A further doubling of the interchanger surface would reduce the temperature gradient by only one-fourth of the initial gradient, while the investment in the interchanger would be four times what it was in the initial design. A similar consideration was found to apply to the cost of water and the cost of larger or smaller pumps.

The problem outlined above is a very simple one and can readily be settled on a thermo-dynamic basis. It is a matter of general judgment as to how extensively this sort of refined calculation can be indulged in, and where refinements of calculation are rendered unjustifiable by elements of doubt in fundamental data. Such points are too often settled on snap judgment. Preliminary check calculations can be made very briefly, to show whether more involved studies are justified in any specific case. It is again a matter of judgment as to whether special developments are justifiable, and where less efficient and convenient standard material and apparatus should be used. The temptation always is for an engineer of a scientific bent to indulge in hair-splitting detail work at the expense of the more crude but commercially sound processes. No general rule can be laid down in such cases, and it is only a matter of many months of trial to decide such a point.

PLAIN REPORTS TO CUSTOMERS

Reference has been made to the matter of making reports clear to the layman. For use in our industrial work a general proposition has been laid down that the whole report should be contained in the first paragraph, and this, we believe, is a matter of general value in business correspondence. A report should read about as follows:

> "Dear Mr. So and So: I have investigated your plant. It is costing you at present $...... a year to run. With the changes recommended below you can run at $...... per year, making an annual saving to you of $......
>
> "The elements in your cost are so and so. The elements in the cost as we recommend you to operate your plant, and including fixed charges on the improvement are so and so. This realizes for you a saving of such and such an amount, which can be capitalized at (any reasonable percentage) to (such and such a number of dollars)."

Here would follow detailed statements and then a brief resumé. This resumè is important. The letter starts with a proposition that attracts the man; assuming that he has to be convinced, the proposal is made in concise, easily understood language; and the resumé confirming the project leaves the desired favorable impression.

Sometimes we meet conditions of operation which put it beyond our ability to show any savings by the use of our power. In such a case we frankly tell the man so, even though we could secure his business without his knowing that it was not the most advantageous thing for him to do. In doing this we outline simply and briefly the reasons why, in this particular case, we cannot serve him. This is very important; otherwise this same man, in talking with his neighbor on some casual meeting might say, "Well, I just had another illustration of the exorbitant prices charged by the local power company. They spent the last three weeks looking over my plant, and when they got through they had to give up the proposition. I am going to put in a gas producer plant. Better think it over for your own plant."

Instead of this condition the process outlined above works out something like this. Mr. So-and-So meets his neighbor and says, "Say, those electric power people are a pretty progressive crowd, and they are on the square, too. I have had them looking over my plant to see if they could do anything for me, and they gave me a pretty frank and honest report. Why don't you talk to them about power for your new factory? If there is not anything in it for you they will tell you so, and they will tell you why."

Sometimes it seems that in this sort of work we are going beyond the legitimate scope of the central station company, and treading on the toes of consulting engineers; but the facts are that people do not retain the right kind of consulting engineers to do this work, and that the central station companies must do something of this kind in order to get the big business. They cannot sell power on their own good will alone. This sort of thing might sell neckties, but it does not sell goods to the man who is seriously interested in getting a return of 100 cents on every dollar that he spends. The philosophy is, in short, the same as that of a large manufacturing concern that does a great deal of gratuitous engineering for its customers. There is the same objectionable reaction upon the practice of the consulting experts, and the same beneficial results to the customers.

One of the elements entering into the work is the use of good judgment in deciding where only the best technical work should prevail and where the work may be made cheap. There are a great many cases where a business will not bear the burden of superlative excellence. In such cases the next best thing must be done. An example in point is that of elevator service.

APPLYING MOTOR DRIVE TO OLD ELEVATORS

We often have occasion, in shutting down steam engines in factories, to go into the matter of re-equipping the elevator drive. Many old factories are equipped with spur-geared winding drums for the elevator hoists. The drums, driven by open and cross belts, are started by means of clutches which are inter-connected with a mechanical brake. It is eminently undesirable to have these belts operating continuously, especially where the operation of the elevator is highly intermittent. In the nature of things the belts are run at comparatively slow speeds and at fairly high tensions; they are in general heavy and short, and the cross belts in nine cases out of ten are worn to a smooth glossy surface from rubbing between the two sides. This represents a considerable waste of power continuously throughout the day. It is not particularly satisfactory simply to put in a motor belted in place of the old line shaft, and the possibilities of the car running down or up according to the relative loads and counter-weights are, to say the least, unpleasant. The geared hoist, of course, is liable to this difficulty, where a worm-driven hoist would prove self-locking. To take care of such cases, we have very often purchased back-geared motors with solenoid brakes on the motor shafts. Such a motor will, in general, be purchased without a back shaft, and the bearings altered to fit the drive shaft of the elevator mechanism, thereby affording rigorous alignment to the gears, and forming a support for the back part of the motor. The front part of the motor is then fastened to the floor or ceiling, as the case may be, by means of a flexible stud, giving a suspension similar to that used on street railway cars. We have adopted a type of starter in which the starting resistance is cut out by the progress of the car, so that all the operator has to do is to pull a rope connected to the line switch. In case of failure of power, or in throwing to the off position, the solenoid brake takes care of the stoppage of the car. Now, this equipment is manifestly not of the best. It does not contain many of the improvements which modern electric elevators carry, and is not a pretty thing to look upon, but it is by all means superior to the old me-

chanically-driven device, and can be supplied at less than half the price of a really up-to-date rigging.

GEAR DRIVES

There is probably more bad engineering done in connection with gear drives than in any other detail of which the writer has cognizance. This detail was met early in our work and a general rule has been laid down, from which we have as yet seen no reason to depart, namely, that the bearings for any pair of gears should be rigidly attached to one another in such a way as to be absolutely self-supporting on a self-contained base. No recourse whatever may be had to wooden support and lag screws, and all bearing pedestals must be secured by means of dowels. Lag screws will cramp into the wood and permit a spreading of the gears, while the ordinary bolted job, where alignment is dependent on friction, shows the same shortcoming under repeated jars. It does not take much spread of the gears to absolutely defeat all the advantages of geared drive in the way of efficiency. It is not sufficient to prevent spreading only, but any warping or twisting action between the shafts must be avoided. For this reason the torsional rigidity of the supports must be maintained. The ideal way of accomplishing this is by means of a ribbed casting, but pattern work comes high; therefore for these little odd jobs where two or three castings from a given pattern would be the maximum, recourse must be had to structural work. There are various means of securing this, and no general rules can be laid down, except that the designer should be thoroughly conversant with the general theory of structural mechanics.

In this same connection it is interesting to note that many designers fall down in the matter of judgment as to where rigidity should purposely be avoided. The condition is highly analogous to that obtaining in the matter of insulation. Some time ago the writer had occasion to use some oil switches manufactured by a thoroughly representative and responsible company and was surprised to find that the switch cases were arranged to be supported on marble slabs. This seemed to be a most vicious practice, as the responsibility for the insulation from earth was divided between the porcelain bushings of the switch case and the marble. A cracked or dirty bushing might readily have resulted in loss of life by raising the switch frame to a potential approaching that of the line. These slabs were eliminated and the switch frames fastened to

channel irons connected to earth, thereby grounding all parts of the mechanism not supposed to be at line potential.

A similar condition obtains where more than two bearings are used on the shaft. Theoretically speaking, it is impossible to align these bearings so as to avoid all undue pressure on account of inexactitude in the alignment. The result is that a short, sturdy shaft cramps in one or more of the bearings. For this reason we have made it a quasi-standard practice to deliberately introduce elements of flexibility, such as that cited above, where the motor is supported by the shaft that it drives and is free to move slightly so as to adjust itself to any displacement between the driven shaft and the floor or ceiling. Where the support of two parts of the mechanism is carried to different objects, and where the stresses involved run into many hundreds of pounds, it is manifestly impossible to do much in the way of relying on a strict maintenance of the relative positions.

A case in point is that of a brewery in which the mash tubs on one floor were driven by motor mechanism on the floor below. The building was an old ramshackle affair, and under the varying conditions of loading in the tubs, the floors approached or receded from on another by at least one-quarter of an inch. The effect on the gears can readily be imagined.

GEAR VS. BELT DRIVE

It may be interesting to consider some of the elements that enter into a selection between gear and belt drive. In general where speeds are high and adequate center distances possible, there is little to be said in favor of gear drive. But where slow speeds and the consequent high stresses obtain and especially in cases of intermittent loading, belts are highly disadvantageous. In the nature of things it is necessary to carry pretty stiff tensions and heavy belts. During the light load periods these tensions create practically as much bearing friction as during the heavily loaded periods, and the running of a stiff belt over a comparatively small pulley represents a continuous using up of energy in repeated bending and unbending of the belt. Moreover, when the power load comes on, such a belt will show a very material slippage. In such a case, drive by means of cut gears or by silent chain is by all means desirable. If the intermittency of the load is very sharply marked, the motor should either be a high resistance induction motor, or a compound-wound direct-current motor in order to avoid the objectionable hammering of the gears and to minimize the sharpness of

demand on the line. This latter factor is of the greater importance to the central station company because of its bad influence on the lighting load. A gradual variation of voltage may be made on incandescent lamps without objectionable physiological results, whereas if the change occurs quickly, the results will be far from desirable.

In punch press and similar work, we have found it advantageous to use motors having rather poor speed regulation, and to mount a good substantial fly-wheel on the motor shaft, the fly-wheel taking the pound of the load and the motor slowing down when the sharp demand occurs and picking up during the recuperative period.

MOTOR DRIVE APPLIED TO A BARREL-HOOPING MACHINE

An interesting application of this kind consisted of a motor-drive applied to a barrel-hooping machine. The manufacturer's rating called for a 20 horse-power motor. The machine was equipped by us with a three horse-power motor of the squirrel-cage type, and it has been in operation for some months, handling the work quite satisfactorily. The machine as originally designed was to be belt-driven from a line shaft. We mounted a couple of brackets on the machine frame with suitable diagonal braces to prevent lateral swaying and placed the motor on this shelf. Gears were substituted for each of the clutch pulleys, and one gear driven from the motor shaft by means of a pinion, the other through the intervention of silent chain drive, thereby giving the desirable reversal of rotation for the raising and lowering motion of the pulleys.

It may be interesting to note the way in which we roughly figured out the torque-time curve. The taper of a barrel is obviously the least at the middle, and it is at this point that the wedging action on the hoops is the greatest. Knowing the dimensions of the hoops used and the size of the rivets, it was an easy matter to know how much force would develop the bursting strength of the hoops, and from this, with suitable assumptions, it was a simple problem to determine the load on the motor. A high degree of refinement was hardly necessary as, even if the fly-wheel were made too large, the only result would be a few pounds extra in the casting, which, being a very small proposition in any case, was a matter of but slight moment.

DETERMINATION OF MOTOR SIZE

There are all sorts of ways of arriving at the sizes of motors to be installed, and the methods that would be used in one place

would prove utterly unsatisfactory in others. It has been a common practice among engineers (who should know better) to take indicator cards on steam engine driven plants, and to assume that the indicator card taken when the plant was carrying no-load represented the friction or waste power that would exist at full-load, and that group or individual motor drive would eliminate only this amount of friction. The results so obtained are certainly conservative, but that is just where their chief difficulty comes in, since they may be so excessively conservative as to make it impossible for the central station company to show cause for the adoption of its service. It is obvious that as the belts are tightened up bearing friction will increase, and this at a pretty rapid rate, so that a plant of 300 horse-power indicated full-load, showing 100 indicated horse-power with all the belts running on the idlers, has not a mechanical efficiency of 66.6 percent, but something considerably below this. Where a proposition is so easy that even on such a basis the business can be secured, it may not be worth while to go farther in the matter of refinement, but in general it will be desirable to get more nearly the actual power taken by each machine or group of machines.

Use of Test Motors—The use of a motor to test the power demands on individual machines is a very convenient method, but is at best awkward and somewhat costly. Manufacturer's ratings, on the other hand, are not satisfactory, since the average manufacturer of machinery is desirous of having sufficient motor power installed to cover contingencies in operation, and to allow for a pretty good factor of ignorance on his own part. If machine efficiencies were talked more by prospective purchasers, manufacturers would probably work to closer ratings, but in the present state of the art such is not the case.

The Dynamometer Method—In some few instances it is possible to use a traction dynamometer to measure the torque of apparatus at low speeds, and to calculate from this the power required at the highest speeds on the assumption of constant torque, but this method must be used with caution. We have succeeded in applying it in the case of a few elevator installations, and in the case of one feldspar pulverizing works. In the latter case the grinders consisted of two large burr-wheels mounted at either end of a horizontal shaft which was turned by a vertical shaft driven through a train of bevel gears. The whole mechanism was driven by comparatively low-speed belt drive. We wrapped a substantial

rope around the pulley from which the belt had been removed and, by means of a block and fall giving a considerable speed reduction, pulled the burr-wheels through several revolutions. The use of a spring dynamometer made it possible to measure the tangential pull on the pulley which, from the nature of the case, was essentially the same as would be obtained during actual operation at full-load speed. Check readings obtained by throwing off one grinder, and taking indicator cards before and after, showed the validity of this method.

Rough Calculations—Once in a great while it is possible to calculate our requirements roughly. The writer has in mind one case in which a motor-driven pipe-bending press was being developed for use by our own Company. The torque to be delivered by the machine was calculated by the use of ordinary structural mechanics from a knowledge of the dimensions of the pipes to be bent and a more or less close estimate of the modulus of elasticity of the material. It sometimes pays in a case like this to do a little bit of crude checking. After finding that the ultimate bending moment of 1¼ inch conduit was 450 foot-pounds, we inquired of the wiring department as to the amount of effort that had to be exerted in making bends by hand, and found that a man could, by throwing his weight on the pipe at a radius of five feet, bend it to a form. The inference was then that our figures were at least not of the wrong order of magnitude. Without some sort of check of this kind one is likely to fall into grievous errors.

Our experience has taught us, among other things, that the calculation process is beset with many pitfalls. There is dearth of authoritative information as to nearly every kind of mechanical phenomenon. The laws governing friction are shrouded in mystery. The transmission of heat through, from and to substances, especially at low temperature, is not at all satisfactorily worked out; and most of our information concerning belting and gearing is in the form of a few isolated tests of an empirical nature, not sufficient to establish definite theories. Perhaps the least sasitfactory condition exists in connection with the matter of heating and ventilation.

EXHAUST STEAM HEATING

It may be asked, what has the power engineer to do with the heating of buildings, and the answer is that, as such, he has nothing, while as a central station industrial engineer it is about as

vital as any phase of the work. The chief obstacle to the sale of central station power for manufacturing purposes and for office building supply is that the isolated or private plant can readily utilize its own exhaust for heating. If you consider that at best only ten to twelve percent of the heat energy of steam is converted into mechanical work in an engine, while almost all of the remainder is thrown out into the exhaust, it becomes quite apparent that where power is sold to a manufacturer, who could otherwise heat his building with exhaust steam, the manufacturer must supply the coal equivalent to this 90 to 88 percent; in other words, practically identical amounts of coal will have to be burned in two different places. It is true that such an exhaust heating system involves inefficient power generation during the warm months, and it might, therefore, be urged that the central station company, having the advantage of efficient machinery and large plants, should easily be able to overcome this difficulty. Such, however, can scarcely be said to be the case if one stops to reflect that almost any isolated plant large enough to be adapted to exhaust heating carries practically all the advantages in labor economy, fuel economy, cheap purchasing, etc., that could be carried by a large central station, and that the difference will not be at variance by an amount that will more than cover the burden that the central station company has to pay in the maintenance of a very expensive distributing system, in the metering of its energy and in its bookkeeping.

When all these things have been taken into account, it becomes apparent that in dealing with the larger projects it is necessary to figure closely in the matter of heating, so that when a prospective customer says, "Well, you must remember that I have to use all my exhaust steam for heating, anyhow," it devolves upon the central station man to show him just how much exhaust steam he would really require for heating.

So serious is this use for exhaust steam that in certain sections of our city we know absolutely that there is nothing to be done in the way of supply of power to our prospective customers, and we have for some two or three months now been making a thorough study of the desirability of installing what we choose to term decentralized plants, that is, plants of 400 or 500 kilowatts capacity, installed in office buildings or department stores and pumping electrical energy into our network, which in our case happens to be a direct-current Edison three-wire system, and delivering their exhaust steam into a

network of steam pipes. At first sight this step seems to be retrogressive. We have all been educated into the central station idea, and rightly so, but the condition is paralleled by that in any manufacturing process. The concentration of manufacture in one huge plant becomes desirable up to the point where this concentration fails to effect economies that will offset the increased cost of transportation to the market. Now just this condition obtains in the power business. It is obvious that a 230-volt direct-current system could not be extended very far from a central station without entailing tremendous cost in distribution both in the copper and subway investment, and in the power loss. The alternative would be an alternating current transmission to distributing centers with converter sub-stations, but this again entails a heavy expense in labor, fixed investment and power losses in distributing centers. Moreover, since the heating of office buildings, stores and hotels must be taken care of, there is the imperative necessity for utilizing the by-product steam heat. Here the central station fails, since even leaving aside the restrictions imposed by the location of fuel and water supply, it is impossible to transmit exhaust steam for heating purposes more than very modest distances. In our studies we have found one very interesting fact and that is, considering that our main steam station must of necessity be equipped with modern units of the highest type provided with all condensing refinement, while the decentralized plant would be a non-condensing turbine outfit, and in view of the fact that some 20 percent more equipment must be installed in the main station to take care of feeder drop, $30 000 investment in a decentralized plant will take the place of $80 000 in a central plant.

Now, in order to make all these studies and to present the matter in a true light to the Company's patrons, it is necessary that we should be in a position to predict in advance what their steam requirements will cost, and what their steam heating will amount to, whether this heat is generated by themselves, or supplied from our decentralized plants, hence the interest in technical data on heating and ventilation.

THE ECONOMICS OF POWER SALE

This brings us to the broad question of economics of power sale, and to some of the commercial points which make central station industrial work so fascinating. In the first place, attention is

called to the fact that no public utility corporation is a monopoly, even though it may have exclusive franchise in its own territory. If any man doubts this, his best answer will be to attempt power sales for any public service corporation in the country, and he will find that he is up against about as vigorous competition from isolated plant salesmen, from works superintendents, engine men and boiler men, as he would meet if there were a competing company.

One broad economic principle is worth noting, namely that when a sale takes place under free competition, there is a benefit to both parties. The idea used to obtain in business that the process of barter and sale consisted in stinging somebody; that one man or the other got the better of the sale. Nowadays we know better, and realize that both parties to a transaction are benefited. When you pay five dollars for a pair of shoes you are getting something you value more than the five dollars, otherwise you would not buy the shoes. The man who sells the shoes is getting something that he values more than he does the shoes, otherwise he would not take your money. Salesmanship consists largely in making this point clear in a specific way. Such being the case, another economic principle appears, namely, that under free competition, the price of any commodity must be determined somewhere between the cost of production and the value of the utility rendered. For instance, in the power sale business, the central station company must sell the power for more than it costs to produce, and must sell the power at such a price that the purchaser will reap some pecuniary advantage over what he could by purchasing or manufacturing at the lowest other available cost, taking into account in the process, as a part of the profit to the customer, the advantages of being freed from the necessity of giving his personal attention to power generation, in which he is not expert, and of being freed from the vicissitudes of erratic labor employment, and of more than erratic small generating apparatus.

THE QUESTION OF RATES

Now it is an interesting fact that the cost of generation by an isolated plant for any given service will follow pretty generally the same laws as will the cost of that same service to the central station company. This cost consists of three items, which may be termed *A*, *B* and *C* factors, respectively, and the equation of the power cost per year, either by means of an isolated plant or by a central station

company in serving a customer may be written very approximately $\$ = A + B\,kw + C\,kw\text{-}hrs$; this being the equation to a plane surface expressed in solid co-ordinates, and an expression which is very simple if couched in proper commercial terms, and easily explained to John Henry, the man in the street. The *A* item comprises those costs which are common to plants of all sizes, and independent of their load-factor. These costs are a certain portion of the investment charge, a certain portion of the fuel and of the supplies. Their existence explains why a large plant can be more economically run than a small one, a plant operated for long hours more economically than one run for short hours, since the burden of the *A* item is carried by a larger volume of business. For the central station company this item includes a large part of the billing and meter reading costs, as well as the cost of service construction. The *B* item is obvious. It covers those costs which are dependent on the size of the plant after the *A* items have been paid for, and which exist whether the plant is run heavily loaded or lightly loaded. These are the remainder of the labor charges, a certain additional part of the fuel charges, practically all the supply charges outside of *A*, and all of the investment charges not included in *A*. *C* constitutes those items which are directly concerned in the cost of production, and which are proportional to the kilowatt-hours output of the plant. Now, in actual practice we find it most satisfactory to take a whole lot of data and plot a continuous curve through a set of points practically secured, rather than to build up the various factors, although the building-up operation is used as a check method. Having once determined on this system of charging, it is interesting to note how it may be utilized to secure those classes of customers that are most desirable to the central station company, and which, by the same token, are those which can most readily serve themselves.

The system of charging is obviously the most expensive for the small customer working for short hours. These customers are the ones whose own costs are the heaviest and who cost the central station companies the most. The small power user who uses his apparatus only during a few hours in the year, as, for example, collar and cuff factories, where the lighting load is entirely out of proportion to the power load, and where the well day-lighted buildings require most of their load during only an hour or so of the winter afternoons, thus requiring a large

amount of apparatus to be held idle during over 90 percent of the year. Depreciation and interest charges on this apparatus go on continuously whether it is used or not, and therefore a rate system which will make such a customer pay his portion of the investment charge is desirable. It is obvious that after investment has been tied up to take care of the peak load customers, this same investment can be used very satisfactorily for any customers who can purchase power off the peak, such as, for example, the average brewery, since the power-consuming processes in a brewery are carried on at approximately midnight and in the early part of the afternoon and require no extra generating apparatus or cable system from the central station company, since this will in general have been installed large enough to take care of the lighting peak in the evening and of the heavy traction load at the same time. It is our purpose to remit a large part of the *A* and *B* items for customers who will elect to take their power during certain hours only, these hours being the ones corresponding to the valley in our load curve.

The *B* item we plan to divide into twelve unequal parts, distributed over the twelve months of the year, assigning the larger divisions to the winter months when we have our worst peak and the lighter divisions to the summer months, when there is idle apparatus and non-useful labor. This should encourage the use of our power by such apparatus as is represented by refrigerating and ice making plants and other seasonal industries.

CHARGE FOR HEATING

The economic problem of selecting suitable charges for the decentralized heating plants previously referred to, is a most interesting one, and has been worked out by us in a way that will, we think, prove quite efficacious. The method is entirely novel, not having been used by any of the companies selling heat as a by-product from their plants. On brief consideration, it is obvious that the customer who uses much electrical power and no heat cannot be served from such a plant as economically as one who enables us to use our exhaust steam for heating his building. At the other extreme, it is obvious that the customer who requires much heat and very little power, similarly does not enable us to work most advantageously, since there is no by-product power carried along with his heating. Somewhere in between there is a ratio of heat to power

which is the most economical for us, and at which they can be most economically supplied by the customer himself from an isolated plant. Our charges, therefore, should be made to each customer as if he, together with all the other customers, had power and heat in the ratio in which he does in fact demand these services, irrespective of the fact that the customers may average out to something better than the worst of them. In this way we will give the greatest utility to all for the money received. The way in which we have studied this cost problem has been to figure the investment and operating charges to us under four different ratios of exhaust steam heat to power, and to figure the isolated plant costs under these same four different ratios for plants of several different sizes; our costs, of course, being based on the cost in the plant which we would propose to install for a given district. Now, in the apportionment of the cost of production between power and heat we come to the interesting economc problem as to which should be regarded as the product and which as the by-product, whether most of the operating costs should be assessed against the power, and the steam heat regarded as profit, or whether the heat should take the burden and the power be regarded as net gain. This problem is, for practical purposes, indeterminate, being dependent purely and simply on the relative supply and demand for the two products. We have chosen to consider the matter in this way: It would cost a certain calculable amount for an isolated heating and power plant to deliver the necessary heat and power for the customer. Subtracting from this total amount the *value of the power,* the remainder is taken as the *cost of the heat.* The value of the power is taken as the cheapest power that the customer could procure by any other process, which happens at our Rochester rates to be the price at which we can serve the power or lighting customer. And, in an entirely similar manner the *cost to us* of the heat is obtained by taking the total cost of operating combined plants at the various ratios of heat and power noted before, and subtracting therefrom the value of the power produced, which is the lowest cost at which we could generate it in our main station, it being remembered that in all these costs fixed charges must be included as well as the operating expenses. Having arrived at the cost to us of producing heat, and at the value or competitive cost of the heat if generated by isolated plants, it then becomes a matter of business judgment as to just where the price line should be placed so as to allow for the customer's optimism as to his own ability to pro-

duce cheaply, and to favor that class of business which is most desirable for us.

TEAM WORK

It would not do to conclude without saying a word about the conditions in our Rochester work, which we believe to be unique. While the work in itself is fascinating to the highest degree and brings out all a man's potentialities in both the technical and the human way, the writer has had for some years a conception of organization based upon a few of his own early disappointments, some of them recognizably the result of immaturity and inexperience, others attributable to short-sightedness on the part of the employers. The aim has been, therefore, to get together a group of men who would be personally congenial, and who would pull together outside the office, as well as in. The results have been more than gratifying, as we have a spirit of comaraderie more closely developed than one finds even in his college classes. The writer is anxious to make this a matter of record, as he feels that no description of this work would be adequate without an acknowledgment of the essential help that has been rendered by this spirit of fellowship in the men who have carried it out, a spirit without which what little success may have attended our efforts would have been impossible.

FINANCIAL ASPECT OF THE APPLICATION OF ELECTRIC MOTIVE POWER TO RAILROADS*

F. DARLINGTON

EVER since the introduction of steam power cheapened the cost of hauling and thereby inaugurated a transportation business that had not been previously possible, especially for transportation on land, the location and extent of railroads have been determined by the laws of supply and demand and of cost and earnings. This relation of railroad costs and earnings has been changed in important particulars by the development of electric railroad apparatus. Railroads create their own business, the amount of which depends upon the facilities they offer and the charges they make, and economies and improvements resulting from the use of electric power will lead to ever-increasing railroad traffic and will be a great factor in the future of this work.

By improvements, railroads have steadily reduced the cost of transportation, and their extent and scope have been correspondingly broadened. Previous to the application of electric power, however, the improvements were all the result of development following certain well defined economical lines and were limited by the nature of the steam machinery used. Although certain definite points in steam railroad development have been marked by the introduction of distinctive changes, such as steel rails to replace iron rails, the air brake to replace the hand brake, etc., the steam railroads of to-day are, on the whole, the result of gradual growth following improvements in the steam locomotive and its auxiliary appliances and the extent of steam railroad lines is limited to the profitable use of steam apparatus.

The laws of profit and loss fixed by railroad earnings and operating costs with steam locomotives have resulted in the use by steam railroads of larger and heavier trains without corresponding improvements in facilities for conducting local and short haul business, the need for which is greater than ever.

Electric power has extended the field of profitable railroad operations in two ways:

1—By providing a cheaper means than steam for carrying on certain transportation work.

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2—By greatly increasing the earnings that can be secured in favorable locations, as has been done by electric trolley roads paralleling steam railroads.

IMPORTANCE OF LOCAL TRANSPORTATION
THE COLLECTION AND DISTRIBUTION OF RAILROAD TRAFFIC

The great bulk of transportation business has its origin or termination, or both, in short local hauls which steam railroads with their heavy trains are ill adapted to supply, so that local hauling is still done by wagons much the same as before railroads were built. At the same time, railroads have greatly increased the total of wagon hauling by increasing transportation business. If we consider the amount of local hauling compared with long through hauls and compare the cost of wagon hauling with railroad hauls, the need for better facilities for hauling local traffic will become apparent. Take as a single example the cost of transporting grain.

The freight on a carload of wheat from Chicago to New York City, a distance of 908 miles, is $3.90 per ton, which is about 0.43 of a cent per ton-mile. The cost per mile of hauling a ton of grain by wagon over country roads varies greatly with local conditions and the distance to be hauled, the nature of the roads, the cost of wages and of horse feed, etc. Without attempting too close an analysis the cost of wagon hauling may be put at 20 to 40 cents per ton-mile, and 25 cents per tone-mile is probably a fair average under conditions prevailing in the United States. Every five miles that a ton of material is wagon hauled adds to its cost from $1.00 to $2.00 per ton, more or less, or in the case of grain, say one-third enough to transport it from Chicago to New York City by rail. Practically every useful substance is transported over and over again by wagons, or by other means than railroads, and the total cost of local hauling is a very large part of the cost of all transportation.

The enormous variety of traffic facilities offered by steam railroads varying from long hauls of heavy merchandise, to the transportation of light packages and mails and passengers, does not meet the demand for cheap hauling, but instead increases this need by augmenting traffic. It has been figured out that the cost of carrying merchandise by teams to and from a certain large railroad in this country is greater than the gross earnings of the road from its freight business.

Last year the annual income of the railroads of the United

States was about $2 400 000 000 gross, or $28.00 per capita for 87 000 000 people. The annual gross railroad earnings in the United States are about two and one-half times the amount of the national debt, but yet there is an immense amount of money paid for transportation in addition to what goes to the railroads, so anything that will improve local hauling is of great importance. Yet in face of all this the tendency of modern steam railroad deveopment is to make railroads more and more carriers of heavy traffic and arteries for wholesale transportation and to minimize or neglect the importance of local carrying in spite of the fact that per ton-mile, local hauling, by wagons, costs something like 25 times as much as railroad hauling.

ELECTRICALLY OPERATED RAILROADS BETTER SUITED THAN STEAM OPERATED ROADS FOR CONDUCTING LOCAL TRANSPORTATION

Clearly, there is urgent need of a more effective and economical railroad means for collecting and distributing traffic, and this business is non-competitive and is the surest source of profit to railroads.

Any business that originates and terminates on points reached by competing railroads is competitive, since shippers have the option of using alternative routes. A vast amount of through business is competitive, since through business largely begins and ends at important terminals reached by more than one railroad. On the other hand most local business originates or terminates with individuals, and individual local shippers in a majority of cases do not have equally available alternative routes between competing lines and must accept what is offered them without competition. Consequently local rates are not subject to variations resulting from competition.

A new aspect has been given to non-competitive business by the introduction of electricity as a motive power. Electrically operated roads are particularly suited for this kind of work. This has been demonstrated by the great extension of interurban trolley roads, which have grown rapidly in mileage and importance and have done this in a number of States where the mileage of steam railroads has shown very little increase. They have been built in many places where local service is needed, especially for local business, either freight or passenger, requiring light and frequently operated trains, and thousands of miles of interurban electric roads are directly parallel to steam railroads and for local business have proven better

than steam railroads because of better earning power and lower operating costs. They have definitely demonstrated by actual operation that there is a wide field for profitable electric railroad business that cannot be advantageously done by steam operated railroads. Steam railroads use every means possible to save a cent on long hauls, but in a majority of cases have consistently neglected the great opportunity afforded by electric power to profitably furnish more and better local accommodations.

CONDITIONS THAT DETERMINE WHERE ELECTRIC MOTIVE POWER IS MORE ECONOMICAL THAN STEAM

In considering the application of electric power to steam railroads two things that must be kept constantly in view are:

1—The increase of traffic and earnings that may be secured by the substitution of electric power for steam power and of electric railroad methods for steam railroad methods.

2—The relative cost of steam and electric power for conducting traffic.

These matters must be considered not only as affecting present railroad operations under present conditions, but broadly as applied to all work of transportation as now carried on by steam railroads, and as it may be increased by changed conditions resulting from the use of electric power.

Any scheme of extensive substitution of electric power for steam power on railroads involves an enormous investment for electrical apparatus, sweeping changes in the methods of operation and in the training of railroad employees, and as steam engines are doing their work efficiently a very great superiority must be proven for electric power before it will be generally substituted for steam. To secure this superiority advantage must be taken of the distinctive features of electric power and its best use will not be made by applying it to the average conditions but to conditions where electric power is especially suited to do the work.

Because electric roads possess advantages over steam roads for conducting local transportation, these roads do much local business which without them would have to be done by wagon hauling, and their accommodations build up local traffic. It has repeatedly happened that electric roads have paralleled steam roads and earned from local business two to four or more times as much as the amount of the local business of the steam road that they parallel. This is

proof that a vast carrying business that is local between the patrons of steam railroads and main railroad lines can be better and more cheaply conducted by electric power than by steam. This applies to a great part of the present business of steam railroads and to a vast local traffic that could be profitably carried with electric cars, but that is now either non-existent for lack of accommodations or is being carried at enormous expense by wagons.

ELECTRIC POWER FOR MAIN LINE OPERATION

It is not intended to imply by the foregoing that through traffic cannot be advantageously handled with electric power, especially in view of the latest developments of electric appliances, many of which have not yet had time to be put into general use. Through trains can be operated with either kind of power. In the present state of railroad progress, especially where it would not be profitable to operate trains at frequent intervals, the best economy will often be obtained by continuing main line operation by steam, but in many places where fuel is expensive and boiler feed water scarce and poor in quality, or where frequent train service will bring better revenue than infrequent, either on main line railroads or on branches or feeders to main lines, electric power has alvantages for doing a vast profitable business, much of which it would not pay to do with steam, and which, if left to steam operated railroads, would not be done at all.

In main line operation there is too wide a variety of conditions to permit a specific statement defining the comparative economy of steam and electric power for moving heavy trains for through business. This work requires locomotives and not motor cars, and for such work it is chiefly a question of the relative cost of locomotive service by steam and electric power. Steam engines are doing this work well. Will electric locomotives do it cheaper or better? Except in a comparatively few special cases, generally through tunnels, electric locomotives are not operating on main lines, but where they are doing so their work is economical and effective. For main line operation there are two principal items of operating expense that are affected by the use of electric instead of steam motive power. These are fuel and locomotive repairs. There is a vast number of smaller items of railroad operating expenses that are affected to a greater or less extent by electric power. There is one other consideration that is not an operating cost and that, in certain

instances, may be of great importance, but in many other cases will not be a consideration at all; namely, the amount of traffic that can be handled over limited track space and in congested terminals by electric power is greater than can be handled by steam power.

ELECTRIC OPERATION INCREASES CAPACITY TO HANDLE TRAFFIC

Referring briefly to this possibility of increasing track and terminal accommodations where electric power is substituted for steam, there are places where the advantages that can be thus secured will be worth millions of dollars. Steam railroad terminals do not readily permit double deck construction with tracks one over the other. On the other hand where a large number of trains are to be electrically handled in a terminal, tracks may be superimposed one above the other, and furthermore, office buildings, warehouses or other buildings may be erected over the tracks. With two decks of tracks instead of one deck, and with the extra facility for handling trains that can be had by electric power, the capacity of railroad terminals may be more than doubled, and in addition much valuable building space may be secured over the tracks. When large freight terminals come to be electrified in cities like Chicago an excellent arrangement can be had by having one set of tracks on a low level for loading cars and another set of tracks for unloading on a higher level, and over these tracks store houses and offices may be built and connecting between all electrically operated elevators may be installed capable, if desired, of handling entire cars.

COAL FOR RAILROAD OPERATION

As already stated, coal is one of the principal items of railroad operation cost that is affected by the substitution of electric for steam power. This is such a tremendously variable item in different kinds of steam railroad service and in different sections of country that even if a definite statement could be made of the effect on fuel consumption by electric operation, such a statement would be far from sufficient to determine the economy that would follow in any specific case. On different American railroads the cost of coal varies from about $1.00 per ton, to $5.00 to $10.00 per ton, and the coal consumed by locomotives in different classes of service varies between wide limits. On an engine-mile basis the cost of coal ranges from five cents per engine-mile, more or less, to as much as fifty cents or more. Mr. W. S. Murray in a careful analy-

sis of the consumption of coal by locomotives on the New York, New Haven and Hartford Railroad.* shows the saving in the cost of fuel by electric operations as follows:

Express service	51 per cent saving
Express local service	54 " "
Express freight service	26 " "

The New Haven Railroad makes its electric power with a steam turbine power plant thirty miles from New York City, using coal to generate electricity, and Mr. Murray estimated that if the New York and New Haven Railroad lines were all electrified between New York and New Haven, and New Rochelle and the Harlem River, the saving in coal alone would be $341 470 per year. Subsequent operation by electric power between New York City and Stamford has resulted in a saving in coal of just 50 percent, exactly verifying Mr. Murray's earlier determinations.

Messrs. Stillwell and Putnam in their very complete discussion of the broad question of substituting electric for steam locomotives,* gives the estimated saving in fuel by electric operation 49.5 percent for average railroads in the United States.

There are many opportunities to use water power electric plants for railroads and thus almost entirely dispense with the use of fuel. Some important main line railroads in the United States, though they are in the vicinity of excellent water powers, are conducting heavy traffic with steam locomotives using high-priced coal that costs 40 to 50 cents or more per engine-mile for freight service and about two-thirds as much for passenger.

In Illinois where coal costs railroads generally between $1.50 and $2.00 per ton (average about $1.55 per ton) the average fuel cost is about:

For freight service	$0.150 per engine-mile
For passenger service	0.086 " " "
For switching service	0.089 " " "
Average for all service	0.112 " " "

(Taking account of the number of engines in each class.)

The cost of fuel per train-mile for railroads in Massachusetts in 1907 was, average:

The Boston & Albany R. R.	$0.220 per train-mile
The Boston & Maine R. R.	0.161 " " "
The N. Y., N. H. & H.	0.170 " " "
Average for all railroads operating in Massachusetts	0.170 " " "

*Published in the Transactions of the American Institute of Electrical Engineers under date of January 25, 1907.

To summarize the foregoing in a few words the cost of fuel per engine-mile varies in different localities and for different classes of engines and different kinds of service from $0.05 to $0.50 or more per engine-mile. Where water powers are available the fuel could practically all be saved by building and operating water power electric plants, and where there are no water powers and electric power for railroad operation must be generated by steam plants the saving in fuel would be about 50 percent, more or less.

LOCOMOTIVE MAINTENANCE AND REPAIRS

Maintenance and repairs of locomotives is another item of steam railroad expense that is largely affected by electrification and is so variable that averages are of little or no value for making comparisons of the cost of steam and electric locomotive repairs for any specific case. The average cost of locomotive maintenance for the United States is about $0.09 to $0.10 per locomotive-mile. On a locomotive-mile basis the cost for freight locomotives is about 50 percent greater than for passenger locomotives and the range of cost of locomotive repairs is from about $0.04 per mile for the lightest passenger locomotives operating under favorable conditions to over $0.20 per mile for some heavy freight locomotives.

For railroads in Massachusetts the cost of locomotive repairs, average for 1907, was:

On the Boston & Albany R. R....	$ .146 per locomotive-mile
On the Boston & Maine R. R....	0.052 " " "
On the N. Y., N. H. & H. R. R..	0.072 " " "
Average for all Massachusetts...	0.070 " " "

These locomotives, however, were not all very heavy and many of them were in easy service. On heavy main line railroads, especially where the quality of the boiler feed water is not good, there are important sections where the locomotive repairs average between $0.15 and over $0.20 per locomotive-mile for freight locomotives and about two-thirds as much for passenger locomotives.

There is not a great deal of data to determine the cost of electric locomotive repairs, but such data as is available, backed by the best judgment of many railroad men, points to a cost for heavy electric locomotives equivalent in power to heavy steam locomotives about $0.03 to $0.08 per electric locomotive-mile under condition where steam locomotive repairs would probably be about two or

three times this amount, so that for average conditions, about two to one in favor of electric locomotives is as fair an estimate of the ratio of locomotive repair cost, steam and electric, as can be determined at present. Clearly since there are such wide variations in the cost of steam locomotive fuel and repairs as $0.05 to over $0.50 per locomotive-mile for fuel, and $0.04 to over $0.20 per locomotive-mile for repairs, and since these are the costs most affected by electrification, it is essential to look most carefully at these items before passing judgment on any specific project.

CONDITIONS FAVORABLE FOR MAIN LINE, THROUGH TRAFFIC, ELECTRIFICATION

The electrification of main line railroads will naturally commence at favorable locations:

Where traffic is dense, that is, where the trains are frequent and heavy.

Where steam locomotive coal is costly.

Where electric power is cheap, especially where cheap and reliable water power can be had.

Where steam locomotive repairs are costly.

APPROXIMATE ANALYSIS OF AN EXISTING CASE, GIVEN FOR EXAMPLE

An actual case examined shows about as follows, and there are numerous places in the United States where similar conditions exist:—

An average of 20 heavy steam locomotives pass over a single track road per day, (including several locomotives in helper service on a high-grade section).

Coal costs $0.20 per locomotive-mile, more or less.

Water powers can be acquired and developed for $75.00 per kilowatt, more or less.

Steam locomotive repairs cost $0.15 per locomotive mile, more or less, average.

On one hundred miles of such railroad, electric motive power compared with steam power would show a daily operating expense balance about as given in Table I. (Excluding from consideration all items of operating cost such as wages of locomotive crews, etc., that may not be directly affected by electrification.)

These totals show in a general way about how some electrification schemes will work out, but all such general estimates are subject to wide variations in different specific cases. The figures are

TABLE I—OPERATING EXPENSES.

REDUCTIONS AND ADDITIONS RESULTING FROM ELECTRIFICATION OF 100 MILES OF MAIN LINE WITH ELECTRICITY GENERATED BY WATER POWER.

	Daily saving by electrification.	Cost added by electrification. Daily.
Cost of steam locomotive fuel for 20 engines over 100 miles of track, 2 000 engine-miles per day at $0.20 per engine-mile. Per day................	$400.00	
One-half of the cost of steam locomotive repairs (one-half of $0.15 per mile for 2 000 locomotive miles). Per day............................	150.00	
Other items of saving secured by electric motive power including reductions in cost of maintenance of these rails and ties, saving in water supply, round-house expenses, etc., at about $0.02 to $0.06 per locomotive mile per day, or say $0.03, more or less, per locomotive-mile (for heavy main line locomotives). Note these items very greatly on different railroads. Per day...	60.00	
Other savings secured by electric operation due to quicker movements and more reliable motive power than with steam; trains more easily handled and not having to stop for water and coal, all of which tends to reduce running time and lessen the working hours of train crews and many other expenses. This is difficult to value definitely, but should be worth on a busy main line railroad, 100-mile section, from a possible saving of several hundred dollars per day maximum to at least $100 per day minimum....	100.00	
Against these savings there would be charges for the operation and maintenance of a hydroelectric plant of say 15 000 kilowatt capacity $15 000 to $30 000 per year for labor and maintenance, or say per day...................		$ 70.00
Maintenance of catenary trolley, of track bonds, of high tension transmission lines, transformer stations, etc., per day, say....................		90.00
	$710.00	$160.00
	160.00	
Net reduction in expenses per day..........	$550.00	

made on the assumption that the trains operated are the same train weights by electric as by steam power.

As a matter of fact, all other things being equal, considerably heavier weight trains can be handled by electric power than with

steam power and even the single item of replacing the tenders of steam locomotives with useful cars would be quite important and does not show in the above figures.

To make the saving indicated would require an investment in a complete water power plant and in transmission lines, trolley lines, transformer stations and electric locomotives. Recent advances in electric railroading have made the installation of a plant suitable for the conditions above outlined much more practical and economical than would have been possible a few years ago. The cost of the entire installation would be in the neighborhood of $2 000 000 everything included, and this investment would be reduced by the release of a large amount of rolling stock consisting of steam locomotives and of coal cars used for carrying locomotive fuel, and roundhouses, water stations, etc. The estimated saving at $550.00 per day after paying all electric plant operation and maintenance expenses would be about $200 000 per year.

There are numerous places in which railroad conditions are quite as favorable or more favorable for electric operation of heavy traffic than indicated by the figures just given, but few of these opportunities have received the consideration that they deserve. There are two reasons for this:

First. Much time has been spent in making plans and estimates for changing from electric power to steam in places where the change would not be profitable, generally because traffic is light and fuel and water conditions favor steam locomotives.

Second. Very great improvements have recently been made in electric railroad apparatus that render it possible to make far more economical applications of electric power to heavy railroad operation than would have been possible a few years ago.

RECENT IMPROVEMENTS IN ELECTRIC RAILROAD APPARATUS

A new system known as the single-phase alternating-current system is now in use on over 20 railroads in the United States and on more than 25 roads in Europe. Electric locomotives of great power have been designed and built for operation on this system using high tension overhead trolley circuits. Builders of this class of apparatus are now prepared to furnish locomotives of two or three thousand continuous horse-power capacity and to equip railroads with overhead trolleys that are charged with current enough to supply two or three or more of these mammoth locomotives at

any point along the tracks as may be required. The trolley wires carrying the single-phase alternating current are supported high over the heads of trainmen even when standing on the highest box cars. For several years this system has filled a useful place on interurban trolley roads and on a few steam roads where it has been installed in preference to direct-current trolleys, but its greatest superiority will be found in heavy railroad traction over long distances especially where large high power locomotives are required. The older direct-current system is not used on long stretches of main line railroad where heavy trains require large locomotive units at different points along a track, because for such work it is not economical to install or operate. The single-phase alternating-current system, on the contrary, unlike the direct-current system, is economical for heavy, long distance, main line railroad work as well as for short distances, and single-phase alternating current locomotives of great power are now being built. Street cars and interurban electric roads, and a few short sections on heavy railroads are very well served by direct-current appliances, but the single-phase system has proven advantageous even on many such roads, and for regular steam railroad conditions, where heavy trains are hauled long distances, the single-phase system is highly suitable. Especially within the last year or two since single-phase electric locomotives of great power have been designed, the opportunity in many places is excellent to secure good savings by heavy railroad electrification. It should be remembered that though electric railroads have been in process of development during the last fifteen or twenty years, their present extensive use is not by any means an indication of what twenty years' applications of to-day's electrical appliances would have done, or can do in the future for railroad work, since side by side with the commercial application of electric power to railroads there has been an advance in the capacity and efficiency of electric machinery for railroad uses.

GOVERNMENT SPECIFICATIONS FOR ELECTRICAL APPARATUS*

THEIR RELATION TO THE STANDARDIZATION CODE OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS AND TO MANUFACTURERS

CHAS. F. SCOTT

THE story of the Atbara Bridge, which an American firm proposed to erect and actually did erect in less time than foreign manufacturers required for the completion of their drawings, is an international example of the American use of standards. The specifications called for the erection of a bridge of definite capacity, without including detail particulars. Had they not been broad enough to admit the American standards, the American bidders would have been excluded, or rather new designs, special materials and long delay would have been involved. We all know that American manufacturing has won its success because things are made in large quantities in standard sizes. It is reasonable, therefore, to expect that the policy of the American Government would be to follow the American method, by putting a premium upon standards and standard specifications. The Government, as a large purchaser, should be the last to create a demoralizing interference in industrial methods by calling for things which are not standard, but involve special requirements and distinctions, often of little or no vital consequence. And yet cases may be cited in which the course pursued by the Government has fostered specialization and irregularity, often involving complication and higher prices with no compensating advantages.

EIGHT SPECIFICATIONS FOR INCANDESCENT LAMPS

As an instance of an extreme condition, and the way in which it was remedied, I cite the following statement which has been given me regarding incandescent lamps.

When the question of purchasing incandescent lamps in large quantities for the several departments of the Government was taken up and investigated about five years ago, it was found that the Treasury Department had one specification; the Bureau of Yards

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*A paper delivered at the U. S. Engineer School, Washington Barracks, Washington, D. C., December 15th, 1909. The paper is included in the graduate course of instruction of the Department of Electrical and Mechanical Engineering of the Engineer School for officers of the Corps of Engineers, U. S. Army.

and Docks of the Navy another; the Bureau of Equipment of the Navy a third; the Quartermaster's Department a fourth; the Library of Congress a fifth; the Government printing office a sixth; the Post Office Department a seventh, and the Bureau of Engraving and Printing an eighth. While nearly all of the lamps were substantially the same and there were but few unusual requirements, yet no two of these specifications agreed and great difficulty was experienced by the manufacturers in understanding just what type of lamps should be furnished under any one of them. To eliminate this difficulty the Bureau of Standards and the Government engineers of the several Departments held a meeting in Washington to discuss the subject of standardization of specifications and appointed a committee which met with a similar committee appointed by the incandescent lamp manufacturers. This joint committee drafted what is known as the Government standard specification and to-day when one department of the Government requests proposals on standard specifications, they are the same as the specifications of any other department, excepting in isolated cases, for example, the Navy Department which requires some special lamps. The standard specifications have eliminated a great deal of difficulty on the part of the lamp manufacturers and the Government engineers as well.

EXAMPLES OF UNSYSTEMATIC SPECIFICATIONS

A further illustration of the same kind is afforded by rubber insulated wire. In this case, however, I am informed that the work has not yet been carried to completion. On the investigation of the specification for standard rubber covered wire, it was found that the Navy Department's Bureau of Equipment had one specification, the Navy Department's Bureau of Yards and Docks another, the Library of Congress another, the Treasury Department another, the Quartermaster's Department another, and there were perhaps one or two other peculiar specifications. On looking over these specifications, they ran a complete line from the poorest competition wire which would comply with the National Board of Fire Underdriters' manufacturing specifications, to the most elaborate specifications for 36 percent Para rubber insulation; notwithstanding the fact that the wire was to be used under virtually identical conditions. In investigating this matter the question of wire for shipboard purposes was taken into consideration and it was found that, with few exceptions, all specifications for wire could be embodied under a few general heads.

A further instance which has been cited in the same connection is with regard to motors. When the question of specifications for motors was looked into, it was found that the same variance takes place in the specifications:—For example, the temperature requirements of a motor covered the entire line from operation at full-load for an hour with a rise of 75 degrees F., to operation continuously for 24 hours at 25 percent overload with a considerably less rise of only 63 degrees F. Such variance in the requirements for motors would apparently cause the manufacturer to make up special apparatus to comply with each specification.

As an example of the non-conformity of specifications and lack of co-operation, it may be cited that in one instance three bureaus were represented in the specifications for apparatus which was to be operated in conjunction, and in which controlling panels for various motors were to be installed in a single room or compartment. One of the bureaus specified a water-tight control panel; another, a switchboard enclosed in a non-water-tight sheet iron case, and the third entirely open panels. Three types of control apparatus were, therefore, to be installed in conjunction, in the same compartment.

SOME SPECIAL FEATURES OF GOVERNMENT SPECIFICATIONS

It is easy to criticise and to show the absurdities in such divergence in specifications as are afforded by the foregoing instances. They certainly are not the result of any established policy, but are examples of certain practices which have grown up under past conditions. In discussing the subject, there are several features which should be considered:

1—The Government as a purchaser has, in many cases, prepared its specifications before suitable commercial standards were established and recognized. This was undoubtedly the case as regards lamps and wire. In the matter of rubber covered wire, for example, one of the largest electrical manufacturing companies, which is an extensive user of such wire, found a few years ago such chaos in wire specifications and such divergence among the regular products of different wire manufacturers, that it was compelled to make its own purchasing department specifications for rubber covered wire. This was not done in an arbitrary way, but by considering carefully the various standard makes and after consultation with the various manufacturers, a standard list was prepared which would meet the requirements and would impose a minimum incon-

venience upon those who furnished the wire. Obviously, it is impossible for the Government to use standard specifications if there are no standards.

2—Another reason why Government specifications are apt to appear arbitrary and call for special apparatus is due to the tendency to enter into particulars and to do designing. It is hard for the engineer, Government or other, to restrict himself to general requirements and not yield to the temptation to enter into details which should concern only the desginer of the apparatus. Ordinarily, the purchaser should not be the designer; or if he is, he must take the consequeneces in restricting competition, in uncertain deliveries, in the extra cost which such products usually involve and he should properly share the responsibility for what he designs.

3—Apparatus may be specified to meet exactly certain definite requirements, although it may be entirely feasible to adapt or modify the conditions so that standard commercial apparatus may be used. For example, in designing a mechanical structure, it may be calculated that an I-beam of certain dimensions will exactly meet the requirements. If these are different from those of standard sizes, its manufacture would involve delay, inconvenience and extra cost. On the other hand, the use of a standard I-beam would probably require only slight modifications in the conditions, or in the arrangement of other parts. Likewise, in arranging machines to be operated by a motor, it may be found that some odd horsepower at some unusual speed, or certain special forms or dimensions of bed plate or bearings happen to meet the exact requirements, whereas, some slight modification in the arrangement might enable a standard motor to be employed. In some instances this cannot be done, as new requirements justify special construction, but such cases are the exception. A demand for something special, when that which is standard might be used, shows inferior rather than high engineering ability. The best engineer seeks to adapt his conditions so that he may utilize the things at hand, the standard products which are upon the market.

4—Some of the men who are called upon to prepare specifications have been trained in Government schools, and in Government service, and have never had experience in manufacturing or commercial work, and hence they often do not have a first-hand technical and practical knowledge of the matters involved. Men who have not had a commercial training may not have developed the insticts of economy of the ordinary commercial engineer, and are

more apt to yield to the temptation to specify what they want, regardless of what is available and regardless of cost.

5—Another alleged reason why Government specifications have not conformed to ordinary practice is that the Government officials are in a position of authority and are sometimes arbitrary, unyielding and apt to be controlled by technicalities. It is quite likely, on the other hand, that Government officials have regarded the manufacturers as inordinately commercial, putting their individual interests far above engineering excellence or Government efficiency. But, whatever weight such considerations may have, it does not fall within the range of the present discussion to enter into personal criticism.

EXAMPLES AND CONSEQUENCES OF ARBITRARY ACTION

Some of the results of arbitrary action, however, both in the issuing of specifications and in the acceptance tests of apparatus, react upon the Government, and place it at a commercial disadvantage. Apparatus will cost more if, when inspected and tested, it is liable to be rejected on technicalities, for the manufacturer must charge extra to cover this liability, and in the long run manufacturers may decline to bid, thereby reducing competition. Much depends upon the spirit in which the specifications are interpreted. An ordinary business man, particularly when he asks for something in which the conditions are new, is satisfied if the specifications are approximated within a certain reasonable range, particularly if the essential and useful elements are satisfactory, and the apparatus accomplishes its purpose. But the Government inspector has the reputation of demanding his "pound of flesh." As an example, a machine adapted for both alternating and direct current was sold to the Government. It was intended to state in the specification that the alternating-current voltage should be "approximately 70 percent" of the direct-current voltage, but a typographical error made the figure 73 percent. The machine was not acceptable because the actual ratio was about 70 percent. It was a matter impractical to change on account of certain inherent elements depending on the arrangement of the windings and the width of the field poles, which proportions were selected in order to secure the best communtation and the best general performance of the machine. In this case, a general approximate descriptive statement (which was a typographical error) was interpreted as a rigid guarantee, and a variation from it was treated as if it were as serious as a

failure of several percent in efficiency. The operating excellence and adequacy of the machines were not questioned, but the miserable little matter of ratio caused long drawn-out annoyance, friction and delayed payments.

In another case, certain small generators were supplied for shipboard operation, which on test were found to have a temperature rise which exceeded the specified limit by a few degrees. The apparatus, if rejected, would be of little or no value to the builder, as it was special. The outfits were eminently satisfactory, except in the trifling excess temperature. The inspector who made the test reported that they were the best machines he had ever seen, and were satisfactory, except in the one point of temperature. The actual temperature rise was a trifle more than the Government specification, but was less than ordinary commercial standard practice. The "pound of flesh" was exacted in the form of a penalty equal to nearly one-half the value of the generators, which turned a manufacturer's small profit into a large loss. The result was that the manufacturing firm which had thus been penalized has declined to make further bids when importuned to do so by this Bureau.

In a certain specification for a machine for a special service, the specification contained a clause the meaning of which was not clear. Literally, it either meant nothing or specified a physical impossibility. A more liberal interpretation indicated a desirable and proper characteristic. The designer took the common-sense interpretation and did what was practical and useful. The machine met its acceptance test satisfactorily, except that it did not literally comply with the impossible requirements. The inspector declined to accept the machine. The matter was investigated. It was found that the original writer of the specification did not know what the particular paragraph meant, but he had seen an attractive phrase somewhere and had incorporated it. The machine was finally accepted, but the conference between the inspector and his superiors had caused a delay in shipment and for this a penalty was incurred, which the manufacturing company had to pay.

FACTORS IN THE PREPARATION OF SPECIFICATIONS

It is easy to criticise specifications and tests and to cite past specific experiences as horrible examples of how things should not be done. It is also easy to demonstrate the value of standard specifications. It is quite another matter to prepare ideal specifications. This is especially true of electrical apparatus where there

must be constant evolution and development to keep up with increasing requirements and improvements in design. Commercial specification should form a definite basis for present work, but they should not restrict progress.

The whole matter of specifications for the purchase of material and apparatus is a complicated one. There are two sides to it, one concerning the user, the other concerning the manufacturer; first, what is necessary to perform the required service, and, second, what is commercially or practically available. The company with which I am connected is a large purchaser of materials. Many of these are ordinary commercial products; others involve special requirements on account of the uses to which they are put. We do not arbitrarily specify what we would like to have, but we consult freely with the manufacturers to determine how our needs can be best met by what they are in position to furnish. We recognize that we are not experts in their products and we enter into conference with them, and in many cases results have been secured through conference and co-operation which could not otherwise have been attained. In a few cases, we have been accused of having scientific experts, who do not know the practical uses and essential qualities of the material, write up the specifications, using various scientific terms and proposing theoretical and scientific tests. Such a specification is usually modified by conference. Our real aim, however, is to write specifications which will provide a reasonable, practical measure of the ability of the material to meet the requirements for which it is to be used.

A. I. E. E. STANDARDIZATION RULES

A number of years ago, the American Institute of Electrical Engineers recognized a confusion among manufacturers, consulting engineers and users, which arose from imperfect standards. There was a topical discussion on the stardardizing of generators and transformers at a meeting in January, 1898.

It was pointed out that while it would probably be impracticable to establish definite sizes or lines of apparatus that would be satisfactory to all concerned and it should not be the object of the Institute to introduce standards which the evolution of business would soon render useless, yet there were certain features which could properly be taken up by the Institute, notably the definitions of terms used in specifications, uniform methods of rating apparatus, methods of conducting tests, etc. A committee was appointed

and its report was issued in June, 1898. This report has been revised twice and was issued in its present form in June, 1907, as the "Standardization Rules of the American Institute of Electrical Engineers." Various matters relating to definitions of terms, performance specifications and tests, which may be adopted in general practice for making definite and uniform the specifications between manufacturers and purchasers, are presented in a simple, practical way. No attempt is made to dictate sizes, speeds, dimensions, and the like. The aim is to define what a specified load really means and how it should be measured; what elements are involved in efficiency and how they should be measured; what constitutes a reasonable rise in temperature and how temperature should be measured. These standardization rules have been proposed and revised by a large representative committee, including experts connected with government bureaus, engineers from manufacturing companies, consulting and operating engineers and scientific experts. The rules have been submitted in preliminary form to expert engineers for criticism and suggestion. They, therefore, represent the best practice. The rules do not purport to be scientifically abstruse, nor to cover all cases; for example, in connection with definitions, this note is given: "The following definitions and classifications are intended to be practically descriptive and not scientifically rigid"; and in connection with insulation tests: "The voltage and other conditions of test which are recommended, have been determined as reasonable and proper for the great majority of cases, and are proposed for general adaptation, except where specific reasons make a modification desirable." It is common practice in commercial specifications and tests to follow methods laid down in these standardization rules Incidentally, they are quite comprehensive in their scope and bring together in concise form a very large amount of engineering data and information. One man who read through the rules carefully remarked that he felt that he had reviewed his whole college course.

ELECTRIC MOTOR SPECIFICATIONS

An admirable presentation of the elements which should enter into a commercial specification is contained in a paper presented to the American Association of Electric Motor Manufacturers by Mr. R. S. Feicht, chairman of its committee on government specifications, in May, 1909. The subject is so well discussed that I shall quote at length from the paper.

The purpose of motor specifications for large consumers is:

1—To insure a uniform grade of apparatus of a satisfactory quality and performance.

2—To enable the purchasing department to place orders for motors without the necessity of securing special engineering advice and with the assurance that the proper motors will be obtained for the particular applications involved.

With these points in mind, let us see whether we can establish some of the important characteristics of an ideal set of motor specifications.

1—They should be written in a clear concise manner so that there can be but one interpretation for each statement and no two parts should be in any way contradictory. These are particularly vital points as the specifications are made up for the use of the motor manufacturer and the representative of the customer, who are usually not consulted in writing the specifications, and, therefore, are not familiar with the intent of the specifications unless the wording of them is unmistakable.

The use of such phases as "perfect mechanical balance," "without sparking," and "satisfactory operation" should be carefully avoided as a literal interpretation of them may cause the rejection of any machine however well designated and constructed. *Perfect mechanical balance* is attained by accident only. *Absolutely sparkless commutation* is practically impossible. *Satisfactory operation* depends entirely upon how easily the witness may be satisfied. It is not right that a manufacturer should be put to the expense of building a motor, the acceptance of which is entirely dependent upon the personal equation of a witness. The wording of the specifications should be such that the manufacturer will be in a position to know positively before the witness test is made that the motor will or will not meet the specifications in every particular.

2—Ideal specifications should contain a general description which will permit the use of any well recognized standard apparatus for the purpose, thereby insuring competition in bids. They should be broad and liberal so as to permit the usual variations in design. It should be recognized by the writer of the specifications that the future development of the motor depends upon variations in the present designs and, therefore, unnecessary restrictions, which serve no good purpose but simply throttle development, should be avoided.

3—Ideal specifications should either omit performance guarantees altogether and leave them to the bidder to supply, or should give them slightly lower than the average, preference being given in the awarding of the contract to motors with the highest performances, other things being equal.

4—Ideal specifications should cover the tests which are to be made to determine whether the motor meets guarantees and, recognizing the unavoidable variations in workmanship and materials and with what degree of accuracy the tests can be made in a commercial testing room, they should specify within what limits the results of tests are to be considered as meeting guarantees.

We often find in specifications for motors that certain points are

covered which should obviously be omitted. In the following a few of these points are noted:

Certain characteristics of a motor are at times specified which in themselves are of no particular moment, but which affect other characteristics covered by the guarantees. In other words, the end is specified in the guarantees and in addition the means of attaining the end are covered by general requirements. As an example of this feature, we often find in specifications that temperature guarantees are specified for full-load and over-load and in addition the question of ventilation is covered. Now, if the temperature guarantees are met, the question of inherent ventilating characteristics is of no importance whatever to the customer. Again some specifications cover efficiency guarantees very minutely and in addition specify that the losses in the motor shall be a minimum or that the best grade of iron shall be used to minimize the losses, etc. Here also, if the efficiency guarantees are met, the question of losses and quality of material used are irrelevant and serve only to handicap the designer.

Some specifications, though apparently written on a liberal and unprejudiced basis, distinctly discriminate against certain designs of apparatus or against apparatus manufactured by certain companies. This practice, of course, should not be countenanced unless the particular design discriminated against is one which is not considered a recognized standard.

Some specifications cover methods of testing which are not considered accepted standards and which, therefore, involve the manufacturer in unnecessary expense in preparing for witness tests.

The principal defect of the present Government specifications is that they do not, in the majority of cases, permit the use of standard apparatus which has proven satisfactory to the general trade. It is inconceivable that the requirements of the Government should be such that it is necessary for manufacturers to build a special line of motors for its use. We do not believe that any such necessity really exists, excepting for apparatus to be used in the equipment of war vessels. In this paper, we are not referring to this class of apparatus, but simply to that which is used by the Government for land service in applications similar in all respects to that of ordinary users.

The types, classifications, and nomenclature of the present specifications differ from those of the A. I. E. E. and A. A. E. M. M. which we now consider recognized standards.

The most elaborate witness tests are specified to be made at the expense of the manufacturer. We see no reasonable excuse for the Government requiring more elaborate tests than are required by other users, nor can we see any necessity for witness tests being specified for all motors.

We see no reason for the Government specifications not being of such a character that they may be used by the small consumer and public in general, as guides in the purchase of motors without the fear that unnecessary special features will be involved, which will interfere with prompt deliveries and increase the cost over that of standard apparatus.

The frequency with which Government specifications are issued is

one of the greatest objections to them. The present specifications have been in force less than a year when completely new ones are proposed. Since January, 1902, four sets of specifications have appeared, making an average of one in about every twenty-two months. If these specifications are made up properly, they should hold for a much longer period unchanged, and, with slight changes and additions to keep pace with the development of the apparatus covered by them, they should remain in force indefinitely. It is practically impossible for a motor manufacturer to change designs of motors as rapidly as the Government specifications have been changed without serious losses from apparatus rendered obsolete, and it is, therefore, very desirable that the new specifications be made to agree with the most modern practice and that changes in them thereafter excepting for good cause be discouraged.

As indicated, the paper from which the foregoing extracts are taken was presented before the American Association of Electric Motor Manufacturers, an association which is accomplishing some highly sastisfactory results. Its methods may be taken as a good example of the right way to do things. The manufacturers have gotten together with a view of standardizing their products. By invitation of the Bureau of Construction and Repair of the Navy Department a conference was held in Washington on May 28 and 29, 1909, at which were represented six bureaus and nine motor manufacturers, a total of twenty-eight men. Preliminary specifications had been issued by the government engineers; these were freely discussed, paragraph by paragraph. A final specification has since been issued substantially agreed upon and practically conforming to the rules and recommendations of the A. A. E. M. M. These specifications apply to all departments of the Navy Yards and Stations and are suitable either for the government or the public. They were issued after Mr. Feicht presented his paper; hence his criticisms were directed at the earlier specifications and not those now in force.

After the conference Electrical Expert Aide, M. W. Buchanan, of the Bureau of Construction and Repair of the Navy, made the following statement with regard to the way in which the work had been done:

"The valuable discussions on points where opinions diverged and the interest maintained throughout a rather long and tiresome conference, also the cheerful spirit which obtained under trying conditions, were all the subject of very favorable comment by the officers of the Bureau."

THE BUREAU OF STANDARDS

Obviously, it should be unnecessary for each of half a dozen or more bureaus and departments to prepare its own specifications

for the same thing. There should either be a conference between departments, or some one department should prepare the specifications. While this could not be carried beyond certain limits, there is a very large list of ordinary standard productions, the specifications for which could be satisfactorily prepared in this way. This method has been carried out by the Bureau of Standards with respect to incandescent lamp specifications and electrical measuring instruments, and specifications are now being prepared for transformers after consultation with representatives of the governmental departments and several manufacturers. This is certainly a logical and sensible method and is capable of great benefits to the government.

Standard government specifications, prepared in conference with the manufacturers, including tests which will determine the practical utility of the apparatus, and acceptable both to the government and to the manufacturers, will not only benefit both parties, but will be accepted by the public. Therefore the government, instead of being a disturbing element in industrial manufacture, may become a useful instrument in establishing standard commercial specifications which will be a great aid in standardizing American products. Both the general public and the manufacturers would welcome such specifications, assigning to them the weight which should properly be attached to engineering work of the government.

There has been very substantial progress away from the conditions which are exemplified in some of the instances of unsatisfactory specifications and tests which have been cited. There is a change from the old-time attitude, in which the Government in an ill-advised or arbitrary way, gave little consideration to commercial standards and methods, and, on the other hand, in which commercial interests looked upon the Government as a legitimate field for the sale of poor apparatus at high prices. There is a growing disposition within the Government bureaus to work together in engineering matters along the lines which modern business development has shown to be the most efficient. There is every reason why harmony and co-operation between departments and between the Government and commercial interests should lead to mutual advantage. The Government should foster the best industrial methods and practices. The engineering and commercials interests of the country should take a pride in Government work—the Government is theirs and they should, with a broad patriotic spirit, take pride in the excellence and economy with which its engineering functions are performed.

THE TESTING OF INSULATING AND OTHER MATERIALS*

THE DESIRABILITY OF STANDARDIZING

C. E. SKINNER

TWO passengers on a transatlantic steamer, both utterly worn out from weeks of preparation in the heat of summer for an extended trip, one representing a manufacturer of insulating materials, and the other a user, were reclining in their steamer chairs some little distance apart, the first day out from New York. The representative of the consumers suddenly became interested in a very promising insulating material in the caulking of the seams in the deck, and immediately applied the universal test for such materials, i. e., the application of a finger nail. While in the act he happened to glance at his companion and found him engaged in identically the same occupation. A laugh followed, and it was recognized that the ruling passion could not be avoided, even in mid-Atlantic.

In the test applied both formed a definite idea of the physical characteristics of the caulking material, but neither could describe these characteristics, except in the most general terms. Even with the facilities of their laboratories at their command, they would have had to enter into more or less elaborate explanations as to testing methods, as well as results, before they could have given figures which would be intelligible to each other. This incident serves very well to illustrate the main theme of this brief dissertation on the desirability of standardizing the testing of insulating and other materials.

The subject is so broad that it is difficult to decide what point of view should be taken, and what materials should be included as examples. It is so self-evident to the writer that we have every reason for standardizing our testing methods, and no reason against it, that argument on the point seems superfluous. The difficulty probably does not lie so much in the fact that as engineers we do not desire the standardizing of our testing methods, as in the fact that it requires time and thought and labor to secure such stand-

*A paper read before the American Society for Testing Materials at its 12th annual meeting, at Atlantic City, June 29-July 3rd, 1909.

ardization, and it is therefore usually easier for the individual to adopt his own standards rather than trying to line up with the standards of others. Even when a firm or an indivdual adopts his own standards of testing these are rarely known to others, and as more and more work is done it becomes harder and harder to change to some other method or some other standard, even though it is equally satisfactory as far as actual results are concerned. All previous data are based on a specific set of methods and testing apparatus, and in making a change to a general standard it becomes necessary to have some means of interpreting one's own work in the light of previous tests.

The testing of insulating materials for electrical purposes is comparatively new to the art; dielectric tests, for example, dating back not more than twenty years at the outside. All electrical machinery is composed essentially of three factors:—Conducting material, magnetic material and insulating material. We might add structural material as a fourth factor, but this is almost invariably integral with or extensions of the magnetic material.

The conducting material used is almost invariably copper, and certain essential tests have been worked out to a very high degree of accuracy, and standards have been adopted such that when the conductivity of any material is given in percent those familiar with the art immediately have an exact conception of what is meant. There are other qualities of the conducting material, such as hardness, flexibility, etc., which are not so well known, but for which it would be very desirable to have some definite measure. The committee on specifications for copper from the International Association for Testing Materials is devoting a good share of its energies to testing methods.

Magnetic material, which is universally iron, or steel in some of its forms, has been very carefully studied, and definite means of measuring permeability, hysteresis, eddy current loss, etc., have been established, though not standardized as in the case of the conductivity of copper. It is hoped that definite standards may be evolved and adopted throughout the country for the measurement of the essential qualities of the magnetic material which enters into the dynamo-electric machinery.

In the case of the conducting material and the magnetic material, it should be noted that only one material need be considered in each case. With insulating material the problem becomes far

more complicated on account of the fact that insulating materials are almost invariably chemical compounds instead of chemical elements, and are presented in almost infinite variety. In the early work in connection with electrical machinery and apparatus, insulation and insulating materials were given only secondary consideration, and this, combined with the very great variety available, has resulted in there being very little in common in the testing methods followed different interests. In common with conducting methods followed by different interests. In common with conduct-qualities which must usually be determined in each case, no matter what the material. These are, insulation resistance, dielectric strength, and specific inductive capacity.

On account of the wide variety of physical conditions presented by the various classes of insulating materials in use, physical tests and chemical determinations are also often necessary. We have, for example, insulating material with physical characteristics ranging all the way from light liquids through the paints, varnishes, pitches and gums to the fabrics, papers, moulded compositions in almost endless variety, and ending in the minerals, such as mica, asbestos, and artificial refractory materials, such as porcelain.

Each general class of materials will require its special means of determining the qualities which must be known to properly understand the grade as compared with any other material of the same general class. It is probable that in many classes sufficient work has not yet been done to allow such standardization, but in some of the classes the data should be sufficiently complete at the present time to allow the standardization of the testing methods for determining the fundamental characteristics of the materials. For example, it is very generally accepted practice among those who use oil for insulating purposes to make tests for dielectric strength by immersing a spark gap in the oil and determining the electro-motive force required to strike across this gap when so immersed, this test giving a measure of the insulating quality of the oil. There is, however, no accepted standard for the length of gap, the shape of terminals, the rate of increase of electro-motive force, the limitation of the size of steps in raising the electro-motive force, the number of tests on a given sample, the depth of immersion of the gap in the oil, the temperature of the oil, etc., all of which influence the final results to a greater or less extent.

Again, we are confronted with the necessity of testing moulded materials in almost endless variety and shape. The tests required

for different materials vary to some extent with the use to which they are to be put, but in general it is desirable to know the dielectric strength or resistance to puncture, the compressibility of the material, its brittleness, hardness, ease of machining, fire-proofing qualities, melting point, solubility in different mediums, etc. If standard forms of test samples and of testing methods could be adopted for determining the more important of these qualities, the manufacturer of moulded materials could then present to the user a set of tests made by any reputable testing laboratory, with the assurance that these tests would be understood, and at least a preliminary understanding of his particular material arrived at by a mere inspection of the tests. It is not to be expected that such standard tests will satisfy all requirements, as the individual user will often require special tests to determine the fitness of any given material for his specific purposes. On the other hand, standards will often allow prospective users to determine whether it is desirable or necessary to go to the expense of making their own tests.

Another example which might be cited is the testing of insulating materials of the class known as treated fabrics and papers. In this case the dielectric strength, the flexibility, the solubility of the coating in certain materials, such as lubricating oil, which may come into contact with the material in service, are desirable. For example, results of dielectric tests in volts per mil, obtained in various and sundry ways, are presented, and even such results are rarely comparable with those of the prospective consumer, unless the exact method of testing be known. The length of time of application of the testing voltage, the shape and area of terminals, the amount of pressure used, the temperature of material at the time of test, and many other things influence the result. It would seem to be a relatively easy matter to adopt standards for these various essential points in connection with tests of this class.

With many insulating materials, and in fact with many materials outside of the insulating field, there are no testing methods available at the present time which give a satisfactory measure of their desirable or undesirable qualities. In no class, perhaps, is this more true than in materials which might be classed generally as gums, such as the various mineral and vegetable gums and waxes. Each manufacturer and user has his own methods of arriving at an understanding, as by the finger-nail test, and much of this is frequently left to someone whose judgment in such matters is due to long training from intimate contact with the uses of the

materials in question. Such an individual may deliver a fairly satisfactory judgment in regard to a given material, but it is next to impossible for him, even if he so desires, to give his method of testing to another so that the same judgment would be formed.

Again, it is very easy for one skilled in the testing of mica to determine whether a given sample is hard or soft, or has the necessary flexibility for moulding purposes, but up to the present time, no means of measuring these qualities has been presented which would give these results in numerical figures. This is also true with many other materials and many other qualities represented in the vast array of insulating materials used in the construction of dynamo-electric machinery.

What has been said in regard to insulating materials is also true in regard to some of the qualities among better known materials used in industrial work. Many specifications for copper wire, for example, used for windings of electrical machinery, call for the wire to be "dead soft." A skilled winder will with his bare hands quickly make a test and deliver a correct opinion, but no really satisfactory test is available as a standard to measure whether the material meets the requirement of being "dead soft," this being particularly true in the case of very small wires.

Again, such materials as phosphor bronze, used for springs, receive their spring quality from the amount of cold rolling given after the last annealing. In some cases material is specified to be rolled ten numbers hard. It is quite a different matter to test such materials with sufficient accuracy to determine whether they have been so rolled, or whether the proper spring quality has been imparted to them. The difficulty is farther increased by the fact that the test of materials of this kind must be made in the finished form, as the shape or size of the finished product frequently has a very decided influence on the final result. A standard form of test sample cannot therefore be adopted.

We all recognize the necessity of standards of length, standards of weight, and standards of volume, and yet even these are still subject to long and bitter dispute, for the reason that it would cost the present generation time and money to change to standards which might, perhaps, be better adapted to the needs of coming generations. We have a good illustration in the Congress of the United States not adopting the metric system when it was first presented many years ago, "owing to the expense and confusion which would be created by such change." If the change had been

made at that time, our system of weights and measures would at the present time correspond to that of the countries of continental Europe, and Great Britain would long ago have been forced to adopt the same standard.

It would seem to me to be preëminently the function of this society, and the privilege of its members to coöperate through the society, in such a way as to bring about the earliest possible standardization of tests and testing methods by which we measure the essential qualities of the materials of engineering. As time goes on, it will be increasingly difficult and expensive to bring about such standardization. That such standardization will eventually be required is very well evidenced by the fact that practically all our national societies have committees on standards of one kind or another, and the older the work, the more difficult the standardization becomes. As an example of this might be cited the work of the American Society of Mechanical Engineers in their attempts to standardize machine screw threads. We now have the standards, but they are not universally adopted as yet.

Why should we not do some advance work along the more important lines indicated before individual standards become so strongly intrenched as to make the adoption of general standards difficult, if not impossible? We could use the society as a clearing house for methods of testing, giving them such publicity that those beginning such work may be able to use methods already established. By the spreading of information of this kind, and by the standardization of known methods through committee work, we should be able to bring about results such that individuals could understand each other without a dictionary of methods.

If, for example, a specific form and dimension of test sample for moulded insulating material, and a certain specific method of making dielectric tests, absorption tests, fire-proofing tests, etc., be adopted for such materials, each producer will get the same information as at present, but in such form that he can understand it, though obtained by anyone else testing the same class of materials.

In all such work we must, of course, be very careful not to interfere in any way with the natural development of new and better methods, or new and better materials by testing with standard methods which do not adequately show the qualities which we must know. Neither should we place any restrictions on any manufacturer or user who wishes to make tests other than those which may be decided upon as satisfactory standards.

THE JOURNAL QUESTION BOX

This section of the Journal is open to our readers. Questions should preferably deal with matters of general interest; they should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

379—**Unipolar Generators** — For what classes of service are homopolar or acyclic generators commercially practicable? Can two or more different voltages be obtained simultaneously from one machine? Can such a generator be operated as a motor when connected to a direct-current source of power? F. P. J.

The acyclic generator will operate equally well as a motor or generator and has the same inherent features. The present forms of this type of generator have been designed for application in connection with steam turbine drive because of their adaptability to high speed operation. By making connections to the proper collector rings, it is possible to obtain two or more operating voltages. Such a machine could, accordingly, be operated as a motor on circuits of various voltages. Generators of this type have been used for 600 volt railway service, giving satisfactory operation. They are also used as low voltage exciters for alternating-current turbo-generators, usually by direct-connection to the same shaft. Where a very large capacity direct-current machine is required and a steam-turbine-driven unit is desired, the unipolar generator may be advantageously considered. An inherent feature of the unipolar generator is that it requires only approximately one-fifth the exciting current of an ordinary engine driven direct-current generator. All of the machines in successful operation at the present time are of similar design, the voltage being generated in conductors connected between collector rings. The total voltage is the sum of the voltages between all of the rings. The current delivered is not commutated alternating current, but is direct in every sense of the word. See also No. 22, Feb., 1908. W. A. D. & L. A. M.

380 — **Preparation of Tungsten Lamp Filament**—How is the filament of the tungsten lamp prepared from crude material? A. B. S.

The crude tungsten is treated chemically to refine it and eliminate all impurities. This treating produces a black amorphous powder of pure tungsten, which is then mixed with a binding material, squirted under pressure through suitable diamond dies, gathered on a suitable conveyor, dried and then treated electrically to burn out the binding material and sinter the fine particles of tungsten into a continuous wire. This question can be answered in only a broad way, because of the fact that the processes of obtaining and handling tungsten are all of more or less secret nature, the details of manufacture of the lamps varying with different manufacturers. Some interesting notes on "The Uses and Geological Occurrence of Tungsten," by Mr. T. L. Walker, abstracted from report made to Department of Mines, Canada, appear in The Mining World for September 11, 1909, p. 547. A recent book on "Electric Lamps," by Mr. Maurice Solomon, price $2.00, contains a chapter on "Metallic Filament Lamps," one part of which covers the subject of "The Tungsten Lamp," in which more comprehensive information may be obtained regarding the details of manufacture and operation of the tungsten lamp than can be given in the limited space of The Journal Question Box. B. F. F.

381—Action of Tungsten Lamp Filament—In the tungsten lamp, is the expansion of the filament due to the effect of increase of temperature only, or are there other stresses present which act only while the current is flowing, i. e., is the sag occurring with increase in temperature due alone to the weight of the filament? J. G. Z.

The expansion is due to the increase of temperature. The position of the filament is affected by gravity, sometimes also by the tension of a spring, and to a greater or less degree by magnetic fields, both external and caused by flow of current in the lamp filament. C. F. S.

382—Effect of Wave Form on Meter Readings—In measuring the output of a mercury vapor rectifier outfit, furnishing current for illuminating purposes, I find that a Weston AC-DC voltmeter shows 268 volts, a Weston DC type shows 233 volts, and a Bristol recording AC-DC voltmeter gives a reading of 264 volts. If, in the measurements taken, the direct-current voltmeter is correct on pulsating current, what causes the AC-DC meters to give so much higher indication? The three instruments give the same voltage reading when connected to a storage battery circuit. W. H. K.

Nearly all commercial AC-DC voltmeters are of the dynamometer type, i. e., having one moving and one fixed coil and no iron. They measure the effective or square root of the mean square voltage. The direct-current voltmeter is of the permanent magnet type, and measures average values if the voltage is of a rapidly varying nature. Pulsating direct current, like alternating current, has a higher effective than average value. The reason that the two AC-DC voltmeters check on battery current and not on rectifier current is possibly that one of these meters is of a type having some iron used in the moving element, thereby causing different behavior on circuits having a steady e. m. f. than on those having fluctuating wave form, due to the different degrees of saturation of the iron. See article on "The Action of Direct-Current Meters on Rectified Circuits," by Mr. Paul MacGahan, in the JOURNAL for November, 1909, p. 700. H. M. S. & H. W. B.

383—Method of Depositing Electrolytic Film on Aluminum Lightning-Arrester Plates—From instructions at hand for preparing the circular plates used in aluminum electrolytic lightning-arresters, by depositing a film or charge thereon, the diagram of connections was assumed to be as shown in Fig. 383 (a). The results, however, were not successful. When the circuit is first made the lamps are supposed to burn brightly for an in-

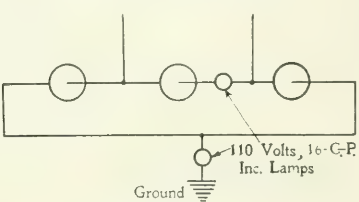

FIG. 383 (a)

stant and then diminish rapidly to darkness, thereby indicating that the electrolytic film has been properly formed. Is the difficulty which has been experienced probably due to too high resistance of the 110-volt, 16 c-p lamps used or is the voltage of the supply circuit insufficient F. G. F.

As a rule, when aluminum trays are first built up, a comparatively large current density is required, sometimes as much as an ampere per square inch surface. Having once been formed, however, the film can usually be reformed by impressing the proper voltage across the aluminum element. One side of the line should be connected to the plate and the other side to the electrolyte in which it is immersed, by means of a proper terminal plate. If two plates are treated at once one terminal is connected to each plate.

When direct current is used it is necessary to reverse the connections to the plate at frequent intervals in order to form the film equally on both plates. A lamp is first connected in series in the circuit to limit the current and, after the film has been partially formed, as indicated by the lamp gradually becoming dim, it is then cut out, thereby impressing full potential on the aluminum plates. The reason for the connections shown in your diagram other than those of the one plate and lamp connected across the line is not apparent. When alternating current is used it will be found that the lamp will not become entirely dimmed because of condenser current which will continue to flow through the circuit. Unless the plate is of small dimension, it may be found that, with a 16 c-p lamp on a 110-volt circuit, the formation of the electrolytic film may take place very slowly. In this case, two such lamps may be used in parallel. It should be noted that to form or re-form a film of the highest possible dielectric strength a voltage three times that mentioned above would be required, the current being controlled as above, by means of lamps and resistance connected in series, and cut out step-by-step as the film is formed. Care should be taken to prevent the electrolyte from becoming contaminated in order that proper action shall not be interfered with. R. P. J.

384—**Deterioration of Storage Battery Plates**—In an automatic signal system employing a number of 60-hr. "Chloride Accumulator" storage battery cells it has been observed that, when making inspection and renewal of the storage batteries, a considerable number of cells are found to be in bad condition, the buttons having so completely deteriorated that they fall from the grid when touched, while the other positive plate will be in good condition, with the button held firmly in the grid. The storage cells of the system are charged from a 500 volt circuit at a current of about two amperes. Why do not both positive plates deteriorate uniformly? R. B. A.

Even with a careful analysis and examination by an expert, it is not always possible to determine the exact cause of such a difficulty. It might be caused by one or a combination of the following conditions: First, it might be due to a short-circuit between the overworn positive plate and an adjacent negative plate, thus throwing the bulk of the work on that side of the cell. Second, impurities may have come in contact with one of the plates at some time when out of the electrolyte, so that when in service this plate became attacked, thus causing it to become worn out before the other plate. Third, since the electrical circuit includes the positive and negative plate, together with the intervening electrolyte, the trouble may be caused by the high resistance or low capacity of an adjacent negative plate shunting the current to that portion of the cell having the proper capacity. Fourth, due to abuse, such as overcharging and letting the cells stand for a long time on open circuit in a discharged state, some of the plates may have been badly sulphated, which would virtually produce the effect given in the first case, shunting all current to the plates of low resistance, thus over-working them. L. H. F. & H. L.

385—**Specification for Magnet Steel**—In working up a specification for steel to be used in lifting magnets, what is the lowest percentage of objectionable impurities that can reasonably be taken as the minimum for material such as obtainable from the average steel manufacturer? R. D. C.

The best quality of steel for use in lifting magnets depends upon the design and service required. Any good mild steel with impurities as low as consistent with good casting can be used. The following analysis shows a good commercial product:—

Carbon .....0.25 to 0.35 percent
Manganese. 0.60 to 0.70 percent
Silicon .....0.25 to 0.30 percent
Sulphur ...0.030 percent or below
Phosphor. 0.030 percent or below

If lower carbon and manganese are used, the steel manufacturing companies will treat it as special and castings may not be perfect. A few blow holes, however, will not harm steel that is to be used for magnets L. W. C.

386—Steel for Field Rings—What would be considered fairly rigid specifications for cast steel to be used for generator rings? R. D. C.

Any good grade of mild cast steel will be suitable for field rings so far as its magnetic qualities are concerned, if it is satisfactory mechanically. To fulfill the latter requirements, the castings should be made of soft steel, manufactured by the open hearth furnace process, and it should be thoroughly annealed. Regarding chemical and physical properties, the following may be taken as representing good practice. It is advisable to have manganese, phosphorus and sulphur as low as practicable, not exceeding, Mn, 0.70 percent; P, 0.05 percent; S, 0.05 percent; ultimate tensile strength 60 000 to 70 000 lbs. per sq. in.; elastic limit not less than 27 000 lbs.; elongation in two inches not less than 22 percent. Standard test specimens are ordinarily required to be furnished to the customer for use in checking the requirements to the specifications under which tests are made. L. W. C. & T. D. L.

387—Comparative Permeability of Low Carbon Steel and Wrought Iron—How would the permeability curve of a low carbon steel (open-hearth annealed steel) for example, of 0.07 percent, combined carbon, compare with that of wrought iron? R. D. C.

The permeability of open-hearth steel with 0.07 percent combined carbon will be equal to, or higher than, that of wrought iron if the manganese in the former is low and the steel is annealed. L. W. C.

388—Use of Steel Wire in Lining Up Shafting—In lining up two horizontal shafts to be connected by means of a flexible coupling, a No. 22 (diameter 0.048 inch) piano wire was stretched overhead with a 15 ft. span, a 75 pound weight being hung at one end of the wire to maintain the necessary tension. In using this wire as a reference line, is it necessary to allow for any sag in the wire at the middle of the span? If so, how much? F. G. F.

No. 22 piano wire (Music wire gauge) is given in mechanical handbooks as having a diameter of 0.052 inch, and an ultimate tensile strength of 650 lbs., and No. 21 wire a diameter of 0.047 inch, and an ultimate tensile strength of 540 lbs. To get so high an ultimate strength, this wire must be made of finest crucible steel. It is very elastic. In order to eliminate any possible sag, the proper method for the above case would be to use a weight of four or five times that suggested. When weighted in this way, a wire of this size could be used in the same manner for cases requiring a great deal longer span than the above. The strength of this wire is so great in proportion to its weight that it may be used under sufficient tension to practically eliminate sag. H. M. S.

389—Treatment of Leather Bellows in Relays—What treatment is required on the leather bellows such as used in connection with inverse time limit relays in order to render them air-tight? S. R. S.

After mixing equal parts of best quality lacquer, such as that used for metal work, and vaseline, apply instantly, carefully rubbing it into the leather. On older forms of relays white lead may be used to make metal joints or hard rubber parts of bellows air-tight P. M.

390—Trueing and Repairing Commutator—(a) What is the proper feed and speed to use in cutting down the commutator on a rotary converter? (b) Is commutator copper hard or soft-drawn? (c) What method would you suggest for filling a pitted commutator? S. R. S.

(a) If there are high bars, the first cut should be made at a peripheral speed of about 100 ft. per min. The finishing cut may be made at as high a speed as the tool will permit; perhaps 200 ft. or more. For the finishing cut a feed of 1/32 in. should be used. See No. 75, May, '08. (The high speed indicated therein may be used in the case of small commutators if the tool will permit.) (b) Commutator bars are hard-drawn to exact gauge. (c) Methods are described under "Shop Experience in the JOURNAL for Dec., '04, p. 685, and Feb., '04, p. 50. The burned or fused material is first removed by means of a sharp tool and the edges smoothed off. If the hole is a large one it should be filled with mica; if small, a mixture of plaster of Paris and shellac should be used. W. S.

391—**Hunting of Rotary Converter**—A rotary converter which has no special device to prevent hunting, has developed two flat spots on the commutator; would the presence of these give the machine a predisposition to hunt? S. R. S.

We see no reason for such an effect. For information regarding hunting, see references on p. 15 of the Six-Year Topical Index. F. D. N.

392—**Alternating - Current Motor With Variable - Speed, Shunt Characteristics**—In an editorial in the JOURNAL for October, 1909, Mr. B. G. Lamme refers to a method of changing the speed of polyphase induction motors by providing the rotor with a commutator and winding similar to that of a direct-current machine. Please give book or article references describing this method. C. E. S.

The principles and characteristics of motors of this type are outlined in a paper on "Repulsion Motor with Variable Speed Shunt Characteristics," by Mr. E. F. W. Alexanderson, Proc. A. I. E. E., June, 1909, p. 643. Note, also, "A Sketch of the Theory of Adjustable Speed, Single-Phase, Shunt, Induction Motor," by F. Creedy, Proc. A. I. E. E., July, 1909, p. 831, and "Discussions," October, 1909, p. 1274.

393—**Oil in Out-Door Type Control Apparatus**—Will induction motor auto-starters operate satisfactorily when the oil has become thickened to about the consistency of vaseline, as sometimes occurs in cold weather? At about what temperature will standard oil, such as used in electrical apparatus, become unsatisfactory? Is it customary to furnish a different grade of oil for out-door use in cold weather? M. O. S.

Increased arcing, with corresponding burning of the contacts, would probably result. The arcing would, of course, tend to heat the oil. Likewise, in circuit breakers, trouble would probably result if the oil were allowed to become thickened to the consistency of vaseline. Where coils are immersed in oil, considerable heat is supplied, which would tend to prevent this thickening. One standard grade of transformer oil freezes at about 21 degrees F. Its insulating properties, although reduced, are not impaired to the extent of rendering it unserviceable from the insulation standpoint. Special oil for use in oil switches operating in unprotected places in cold weather is available. Such a grade of oil supplied by one company has the property of withstanding a temperature of 53 degrees F. before freezing. The use of a special oil under such conditions is recommended.

C. E. S. & F. W. H.

394—**Grounds in Secondary of Induction Motor**—What would be the effect of two or more grounds in the squirrel-cage winding of an induction motor?

A few grounds in the squirrel-cage winding of an induction motor have no appreciable effect upon the operation of the motor. See No. 286 in the JOURNAL for August, 1909. F. W.

395—**Induction Motor Clearance**—What is the proper clearance between the stator and rotor of a

20-hp, 200-volt, 60-cycle, three-phase induction motor? C. R. F.

The general practice of the leading manufacturers for motors of this general design is to use a clearance from iron to iron of appromimately 3/64 inch. R. S. F.

396—**Critical Speed**—When the rotating member of a turbine or like mechanism has its center of gravity slightly out of the axis of rotation there is tendency, at low speeds, for the rotor to throw out on the heavy side. If the machine is speeded up, a certain (critical) speed is reached at which this condition is changed and the rotor tends to throw out on the light side. How can this critical speed be pre-determined from the dimensions of the rotor and the eccentricity? What is the name, cause, and measure of the force that causes a rotating body to tend to place its center of gravity in the axis of rotation? H. V. G.

The following simple experiment aids in obtaining an idea of the actions involved: Attach a small weight to a rubber band, so that the band will be stretched two or three inches by the weight. Holding the end of the band in the hand, note that there is a definite rate of vertical vibration of the weight when the hand is held at rest after being moved slightly vertically. Now move the hand up and down through a small range, beginning at a very slow rate and increasing the rate gradually. When the motion is very slow, the weight follows very nearly the motion of the hand. As the rate increases, the motion of the weight becomes complex, increasing and decreasing in amplitude. When the frequency with which the hand is moved agrees with the previously determined natural frequency of the weight, the amplitude of the motion of the weight becomes greatly increased. As the frequency of the motion of the hand still further increases, the vibration of the weight diminishes in amplitude and when the motion of the hand becomes very rapid the weight remains nearly in a fixed position. The connection between this experiment and the problem of the shaft or armature becomes evident when we remember that a uniform rotary motion may be regarded as composed of two single harmonic motions at right angles to each other. The vibrations of the shaft with varying speeds of rotation correspond in a general way to those of the weight suspended from the rubber band. When the rate of rotation is exactly the same as the natural rate of transverse vibration of the shaft, considered as an elastic body, the vibrations are more pronounced than at other rates of rotation, and this rate of rotation is what is called the critical speed. The vibration is generally limited, in actual constructions such as armatures, by various damping actions, including slipping at joints and imperfect elasticity of materials. The increase in steadiness of rotation when the rate of rotation increases above the critical speed may be readily understood from the experiment with the rubber band. A definite elastic action tending to displace the mass in one direction is so quickly reversed to the opposite direction that the time interval is not sufficient to permit the mass to be displaced very far, and the more rapid the reversals of the elastic actions the less are the corresponding displacements of the mass. A full mathematical discussion of these questions is given by Prof. Stodola in his book on the "Steam Turbine." There is a full discussion by Prof. Arthur Morley in "Engineering" (London) July 30 and August 13, 1909. The latter articles give numerous formulas and numerical examples. A. K.

THE

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Electric Power for Dredging

One has but to study the natural hills and valleys, ravines and gulleys of the earth to realize how vast are the possibilities of carrying materials in suspension in moving water. It is nature's method of moving material. One of the first artificial uses of this ability of water to carry solid matter in suspension was in hydraulic or placer mining, in which water diverted from mountain streams was used under pressure to wash away the deposits of gold-bearing rock, gravel and sand, from which the gold was separated in sluices.

The development of the centrifugal pump of the type known as the "sand pump," which would pass through its chambers coarse materials, opened up another most important field in the handling of subaqueous material. Credit is due to the late Captain Daniel Danes of Schenectady, New York, among others, for demonstrating the possibilities of the use of this type of pump in dredging work. The problem encountered by Captain Danes approximately thirty years ago was that of deepening and widening the channel off the Sandy Hook entrance to New York harbor. Contracts were taken on a yardage basis for doing this work, the prices being figured on the older and slower methods. Experiments were made with the centrifugal pump and, after several unsuccessful machines had been tried out, the sand pump was finally developed to such a point as to make it a commercial success. From that time a great profit was made on the contracts by sucking the sand up with the water and discharging it into scows which were towed out to sea and unloaded.

Recent years have witnessed great improvements in the various applications of the suction dredge, important among which are the two large sea-going dredges used by the U. S. Government in cleaning out the approaches to the Panama Canal and, in fact, in the ac-

tual excavation of considerable portions of the canal proper through the lowlands at its ends.

The article in this issue by Mr. Allen E. Ransom describes in detail one of the most important and promising developments in recent years in this line of work. While the electrically-driven dredge described is equally well adapted to the loading of excavated material on boats for distant disposition it is particularly well adapted to the excavation and immediate transportation and disposition of the materials in filling marshes and in recovering large areas of tide-flooded flats. Among its advantages are the small water displacement owing to the absence of heavy engines, boilers and stores of fuel. As the displacement of an electric dredge is constant, it is much easier to connect such a dredge to discharge pipe lines than to a steam dredge with its attendant varying supply of fuel. The development of this type of dredge opens up great possibilities in the way of recovering marsh land by ditching and draining and more particularly in the way of cutting navigable canals through marshes and depositing the excavated material to reclaim the waste land for manufacturing, terminal and harbor uses.

The application of electric power to dredging work forms an ideal all-day load and is unquestionably economical from the commercial standpoint, as the transportation and handling of fuel to a dredge is particularly expensive and the economy of steam-driven pumps and hoists cannot compare with that of hydro-electric power or electric power from an up-to-date central station.

W. A. Thomas

Vacuum-Pressure Impregnation of Insulating Materials

The year 1892 marked the beginning of high tension transmission work in the United States, the first installation being a 10 000 volt plant at Pomona, California. The writer was engaged in making tests on materials and finished transformers for this installation, and encountered for the first time (but not the last) the difficulty of bringing out transformer leads, which at that time presented a more formidable problem with 10 000 volts than is presented at the present time with 100 000 volts. The design finally adopted was that of a wooden bushing fastened to the side of the transformer case, through which was placed a glass tube with a wall thickness of

about one-eighth inch, the bare wire being threaded through this tube and connected to the coil.

Difficulties arose due to breakdown of the wood. As previous tests had shown that dry wood was an excellent insulator, an attempt was made to thoroughly dry these wooden terminals in a vacuum, and then impregnate them with paraffine. The apparatus used consisted of a small cylinder, heated by means of a gas fire, the cylinder being something over twice the length of the terminal to be treated. The lower half of the cylinder was filled with paraffine and the piece to be impregnated was suspended in the upper half. A vacuum was established, heat was applied and finally the vacuum pump was shut off and the cylinder reversed, immersing the terminal.

This early attempt was later followed by others, larger experimental apparatus being used. Later, commercial apparatus of this kind was placed on the market and vacuum drying and subsequent impregnation became a regular feature in treating various kinds of apparatus, particularly those used in high voltage work. At the present time vacuum drying is recognized as the most satisfactory method known for positively removing all moisture from the insulation in electrical apparatus, and the subsequent impregnation renders the apparatus moisture proof.

In the early days of high tension transmission work there were many mysterious breakdowns, which we now know to have been caused by the presence of moisture in the apparatus. The difficulty experienced in getting rid of moisture is well illustrated by an incident which occurred some years ago in the drying out of some very large transformers after installation. The cases were made vacuum tight, a vacuum was established, and the transformer itself heated by means of current through the coils. When insulation resistance measurements showed that the transformers were dry, oil was admitted. After admitting the oil, which was known to be moisture free, a test sample of oil was taken from the bottom of the transformer and found to contain about 90 percent water. An investigation showed that the transformer case acted as a condenser for the moisture which had been driven out of the transformer core and windings, the water thus formed collecting in the bottom of the transformer tank. It was at once obvious that the transformer case must be thoroughly lagged during the drying process to prevent its acting as a condenser, or some means must be provided for drawing off the water thus condensed. Similar difficulties were encoun-

tered in the early days of the development of vacuum drying and impregnating apparatus.

The article is this issue of the JOURNAL, entitled "The Impregnation of Coils with Solid Compounds" gives some idea of the large amount of work which has been done in connection with this subject. It is evident that to get the best results the operator must have at his command, not only modern apparatus, but also intimate knowledge of the materials and methods such as can be obtained only from long experience in this particular line. Present up-to-date methods and expert guidance make this process one of the most definite and reliable in connection with insulating materials.

C. E. SKINNER

Continuity in the Transmission of Electric Power

The problem of generating, transmitting and delivering power is theoretically simple. In a general way it corresponds to the problems encountered in the proper and continuous distribution of other commodities necessary for our comfort, convenience and physical well-being, such as food, water, ice, etc. All of the latter may be collected in bulk to be distributed to consumers as needed in comparatively minute quantities, provided the supply is available either constantly or at certain intervals. In the distribution of electric power, however, there is practically no storage capacity in the transmitting system and the slightest interruption of the supply means a simultaneous interruption at every point fed by that source. Hence, the distribution of power on a large scale, while theoretically simple, is, on the contrary, involved in disconcerting complications, and the engineer who attempts to take the crude power from nature and refine it until it can be carried many miles over slender wires to the users, and essays to do all this continuously and without even momentary failure, will find nature prone to make many reprisals and to thwart his plans. Only keen foresight and vigilance will enable him to outwit the often hostile elements, and control and guide the power in the channels he has devised. From the nature of this problem only an approximate solution is possible when all conditions are considered. In years past, however, many men have contributed their share toward this result, either by pointing

out the dangers and showing how they may be avoided, or by making clear the somewhat hidden laws of electric power. As a matter of fact, it is surprising how much was done even at a comparatively early date to outline fundamental laws, diagnose electrical troubles and suggest remedies.

Some of the most important early work in the general field of protecting electrical circuits from interruption was carried on by Mr. A. J. Wurts, who took up the work at a time when the lightning arrester for an alternating-current station consisted of some brass saw teeth mounted on a hard rubber base on which were placed some open lead wire fuses. The lightning arrester and often the dynamo had to be repaired after each discharge. He developed several forms of arresters depending upon the expansion of air heated in an enclosed chamber. The heat was produced by the arc following a discharge, and the pressure generated was used either to blow out the arc or to separate the electrodes. He also discovered the non-arcing properties of certain metals and invented the non-arcing metal lightning arrester, which, with the addition of certain auxiliary resistances desirable on circuits of large power or high voltage, is in general use to-day. Mr. Wurts recognized that the problem was not merely one of devising apparatus but of studying the conditions, and he made a number of prolonged trips of observation to some of the early power plants in the West, to determine the conditions in the field. His pioneer work and the part he took in engineering and electrical societies did much to lay the foundation for the investigations and apparatus which have followed.

The article, in the present issue of the JOURNAL, on "Static Strains in High Tension Circuits" by Mr. Percy H. Thomas, on account of its accurate analysis of electrical stresses from so-called static sources, has come to be regarded as a classic on this subject.

It is expected that a number of similar articles will follow, written by different engineers and covering various phases of high voltage operation and service continuity. Lightning and static stresses in general form but one of the elements affecting reliable service. In fact, the records made by some operating engineers indicate that but twenty to twenty-five percent of the interruptions to service are to be ascribed to such causes. For that reason it is intended that some of these papers shall cover other features of the transmission problem.

R. P. JACKSON

Modern Large Electrical Machinery

It is now usually recognized that the greatest economy of operation combined with the smallest investment can be obtained only by increasing the magnitude of the generating power plant and the size of the individual units used therein. Thus we have seen our power plants growing larger and larger. The distributing machinery, such as transformers, rotary converters, and motor-generators, has kept pace with the growth of the generating plant, and the size of these units has increased correspondingly. Ten years ago a rotary converter of 1 000 kw capacity was considered very large. Five years ago a 2 000 kw unit was the largest of its kind, whereas to-day 3 000 kw rotaries have been built and successfully operated. Where the frequency of the supply circuit is above 25 cycles, the motor-generator set has been developed for the large units.

In an article in the present issue a 3 000 kw, maximum continuous rating, motor-generator set is described as a newcomer, in point of size and speed, in the great family of large electrical machinery. Such large units can be built only if all materials which enter into their construction are utilized to the limit; if, in the parlance of the shop, the armature copper and the field copper, the armature iron and the pole iron, are worked as hard as our increased knowledge permits. That great economy in design and construction is not incompatible with high efficiency and cool operation, has been demonstrated in this case, as in many others, by the remarkable performance data obtained. So it has been shown again that economy in performance is not divorced from economy in cost.

One more word on the feat here accomplished of commutating sparklessly 3 800 kw at 300 r.p.m., and without a sign of distress with the circuit breaker opening at this load. Such performance would have been deemed wellnigh impossible a few years ago and indicates steady and important improvement in design.

With all possible refinement in the means of obtaining commutation, combined with the utmost refinement in the means for carrying off heat, results have been obtained which justify the hope that limits apparently impassible are gradually being pushed out farther into the region of the unaccomplished.

B. A. Behrend

ELECTRICITY IN DREDGING ON PUGET SOUND

ALLEN E. RANSOM

PUGET SOUND, with the rapidly growing cities on its shores, has opened a field for the electric motor in large units. The mountain streams from the Western slopes of the Cascades and the glaciers and snow-clad peak of Mount Rainier, make available an enormous source of water power. The growing industries of the Puget Sound district have already utilized several hundred thousand horse-power through the medium of hydro-electric generating plants. With such a source of power behind them, immense flour mills using 250 to 1 200 horse-power each, are becoming numerous; cement mills are electrically driven by the mountain water

FIG. I—GENERAL VIEW OF DREDGE

power; sluicing plants to re-grade the hills of Seattle and Tacoma, use over 4 000 horse-power; the street railway systems of Bellingham are driven by power generated at the falls of the Nooksack and fed from the snows of Mount Baker; those of Seattle, Everett and Tacoma obtain their power from the well-known generating stations at Snoqualmie Falls and at Electron on the Puyallup River, and light and power for Olympia is generated on the spot at Tumwater Falls. These various industries are using to-day a grand total of over 75 000 horse-power and are requiring constant additions to the present hydro-electric installations.

These same streams, after leaving the power plants forty miles back from the Sound, go tumbling down carrying with them sand,

rocks, trees, and other refuse. Flowing into land-locked recesses along the shores, they deposit their debris year after year, forming shallows extending out until the sweep of the ocean tide washes them away. Because of precipitous hills paralleling the shores on which Seattle and Tacoma are built, their natural expansion inland is limited, and accordingly the cities have been forced out onto these shallows or tide lands and the sluicing plants are busy grading down the hills and running the dirt and gravel to these shallows, raising them above the high tide, but leaving waterways at the mouths of the rivers which are the natural harbors of these cities.

The confining of these streams naturally increases the amount of deposit from them in their waterways, and dredges are constantly kept in service to keep the channels clear. For a number of years steam dredges were used exclusively, with clam shell buckets,

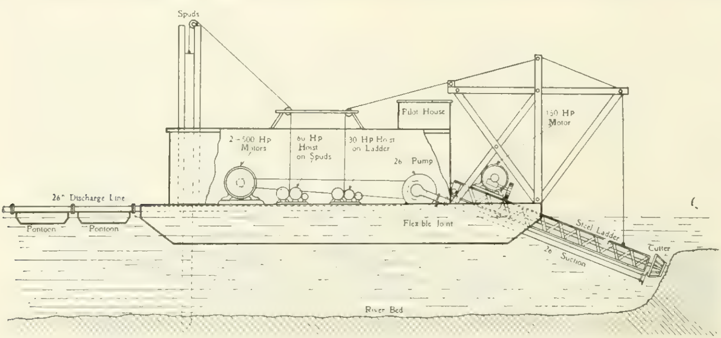

FIG. 2—APPROXIMATE ARRANGEMENT OF APPARATUS ON DREDGE

but these have come to be too small to do efficient service. It is thus that the same power that is generated by these streams is now utilized to clear the harbors and waterways of the Sound cities. The Puyallup river in Tacoma harbor has been a particularly unruly stream, bringing down vast quantities of debris, and to keep the channel clear a dredge of unusually large capacity was necessary. Messrs. Tweeden and Mills, of Tacoma, under the name of the Tacoma Dredging Company, after carefully going over the situation developed an electrically-driven suction dredge named the "Washington," which has proven a great success.

This dredge is built on especially strong and substantial lines, the general arrangement being shown in Figs. 1 and 2. The electric power for the operation of the dredge is taken from one of the 60 000 volt, 60 cycle, three-phase transmission lines of the Seattle-

Tacoma Power Company, and stepped down to 2 300 volts at a sub-station located on the filled-in tide land, as shown in Fig. 3. From it the distributing circuit is carried on a temporary pole line along the water's edge. A three-phase flexible cable of sufficient capacity to transmit electric power equivalent to a total of 1 500 horse-power extends from the switchboard panel in the pilot house of the dredge along the pontoons supporting the discharge pipe, and is connected to the 2 300 volt line at convenient points as the dredge works along. As the length of this cable is nearly 3 000 feet, the dredge can operate over a wide range without the necessity of interruptions to change the connection at the shore end. The incoming current is

FIG. 3—SUB-STATION LOCATED ON FILLED-IN TIDE LAND
1 500 kw capacity.

distributed from the main switchboard in the pilot house of the dredge, shown in Fig. 4, at which point a totalizing wattmeter is installed.

The electrical equipment of the dredge provides for the operation of the cutter, the spuds, the centrifugal suction pump and several auxiliaries. The cutter is driven by a wound rotor type, 150 hp., 2 300 volt, 690 r.p.m., semi-enclosed motor. The motor is equipped with a special bearing and is connected to the cutter by double reduction gearing. This equipment, which is shown in Fig. 5 is especially designed to operate at the various angles at which the cutter is worked; the normal position of operation of the cutter motor is at an angle of about 45 degrees. It is in operation through-

out the 24 hours of the day. A drum type reversing controller, with grid resistance, located in the pilot house, is used to operate the motor.

The cutter is raised and lowered by a direct-connected hoist, located toward the rear of the dredge, which is driven by a 30 hp., 220 volt, two-phase, 850 r.p.m., wound-rotor type motor controlled, as in the previous case, from the pilot house by a drum type reversing controller and grid resistance.

The spuds, which are the heavy weighted iron shod timbers at the back of the dredge, are operated by the 60 hp, 220 volt, wound-rotor, motor shown in Fig. 6. These serve to brace

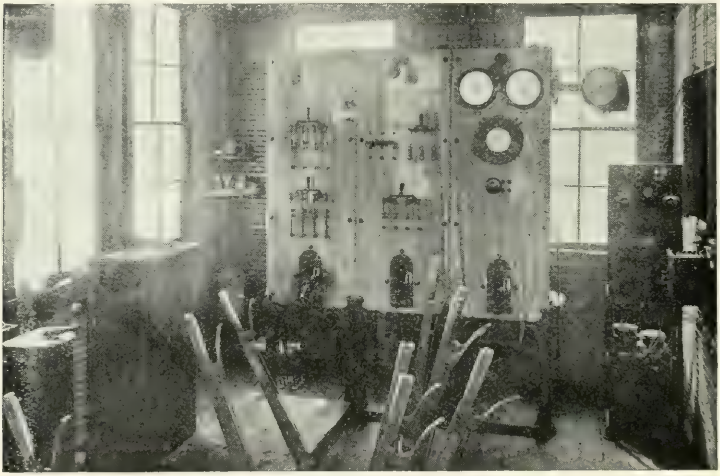

FIG. 4—MAIN SWITCHBOARD AND MECHANICAL CONTROL LEVERS IN PILOT HOUSE OF DREDGE

the dredge as the cutter moves forward into the bed of the stream and can be raised or lowered alternately by a forward or reverse movement of the controlling hoist. By thus swinging the dredge in an arc the cutter is permitted to open up a channel forty to fifty feet wide and cut away the bed of the stream to a depth of ten or fifteen feet. The main suction pipe extends along the steel ladder which carries the cutter, located at the bow of the dredge, and catches the dirt and water directly behind the cutter, drawing it off as it is cut away.

The main suction pump is of the centrifugal single runner, 26 inch type operating at 460 r.p.m. It is located about amidship and is connected by rope drive to two 500 hp, 2 300 volt, self-

contained wound rotor type motors. As the load is constant and the motors are running continuously without any attention from the

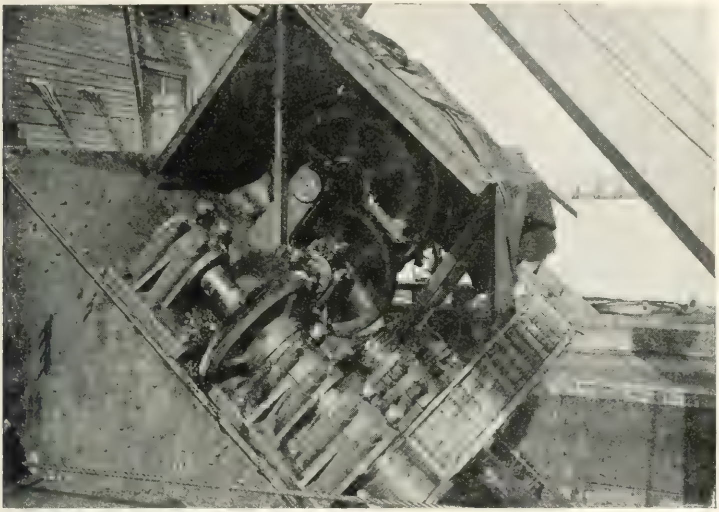

FIG. 5—MOTOR AND REDUCTION GEAR EQUIPMENT OF CUTTER

operator in the pilot house, the starting controllers and resistances are located right at the motors. As originally installed, each motor

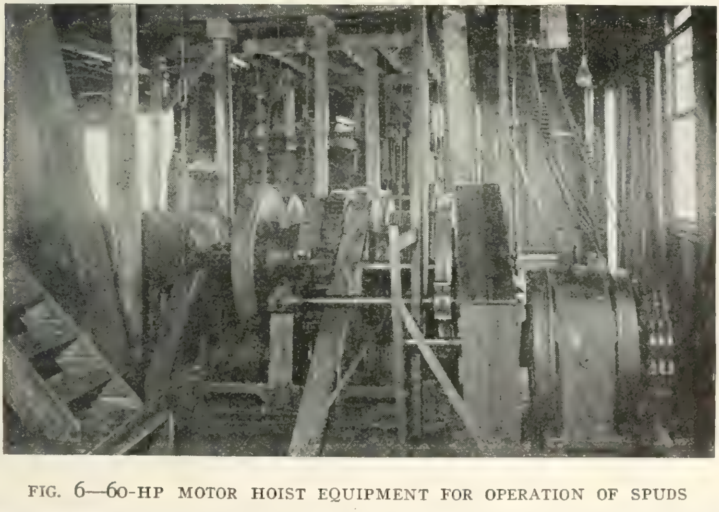

FIG. 6—60-HP MOTOR HOIST EQUIPMENT FOR OPERATION OF SPUDS

was connected by rope drive to a separate pump, the suction forming a "Y" and discharging into the 26 inch discharge pipe. These pumps

were later taken out and the single large capacity pump, with single rope drive was substituted. The two motors are now arranged for operation in multiple and are rigidly connected by means of a common shaft, as shown in Fig. 7.

The water and silt from the cutter is carried back over the stern of the dredge, through a 26 inch wood stave pipe, at a rate of 21 000 gallons per minute. The long continuous discharge pipe, which is to be seen in Fig. 8, is made up of sections carried on pontoons anchored behind the dredge and connected together by flexible rubber couplings; it serves to carry the material to the desired

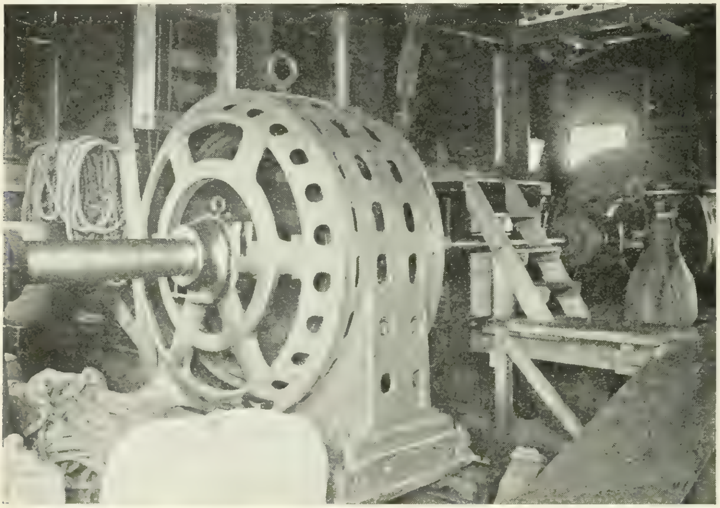

FIG. 7—TWO-MOTOR EQUIPMENT, 500-HP EACH, FOR DRIVING CENTRIFUGAL PUMPS

Rope drive is employed.

point of deposit. This form of coupling gives ample flexibility as the dredge moves up and down or from side to side.

The pipe line extends to the shore line and then continues to the tide land which is being filled in, spouting forth a thick muddy stream (as shown in Fig. 9) from which the water rapidly drains off, leaving a hard packed foundation. This area is enclosed by piling, in which the intervening spaces are filled with timber and brush, so that the rise and fall of the tide cannot carry it away.

The site of the "Milwaukee" terminals, Fig. 10, which a year ago was low-lying tide land, covered with eight or ten feet of water at high tide, and later was filled in to give solid land several feet

above this level, was made by this dredge. The ground on which the sub-station is standing and where the material is being dis-

FIG. 8—GENERAL VIEW OF DREDGE SHOWING LONG DISCHARGE PIPE CARRIED ON PONTOONS

charged, as shown in the previous illustrations, likewise will become the site of docks, manufacturing plants and terminals.

In addition to the above main motor equipment on the dredge there are several smaller motors of the squirrel cage type operating

FIG. 9—DISCHARGE OF MUD AND WATER ON TIDE LAND

The water drains off, depositing the silt; in this way solid new land is built up to a sufficient level above high tide to render the land available for buildings, etc.

at 220 volts, which are used for the driving of auxiliaries. For example, a five hp, 1 700 r.p.m. motor is provided for operating a

lathe, and a 15 hp motor is connected to an air pump used for priming the main suction pump. The remaining auxiliaries are of smaller size.

During over a year of operation very little trouble has been experienced, due to the mechanical or electrical construction of the dredge. It has furnished a continuous load of from 900 to 1 250 hp for 24 hours a day and seven days a week; it has handled thirty

FIG. 10—SECTION OF TIDE LAND CONVERTED INTO BUILDING SITE AS A BY-PRODUCT OF HYDRAULIC DREDGING

million gallons of a heavy solution of mud and water per 24-hour day and thus has demonstrated that this type of dredge is a great success, greatly exceeding the capacity of any steam-driven dredge of equally compact design.

NOTE.—The writer is indebted to Mr. A. W. Tweeden and to Mr. A. U. Mills, of the Tacoma Dredging Company, through whose courtesy the above information and photographs were obtained.

IMPREGNATION OF COILS WITH SOLID COMPOUNDS

J. R. SANBORN

THE rapid development of electrical apparatus in a comparatively few years has been due principally to radical changes in the materials and methods used. Special steels have been developed giving lower iron losses and consequent increase in efficiency. With insulating materials, the development has been toward higher dielectric strength for a given thickness, better mechanical strength and better heat conductivity. Articles have been used that were previously unknown in mechanical construction, some of them possessing certain desirable characteristics in such a high degree that deficiencies in other characteristics have had to be overlooked in the articles themselves and supplied by other means. Most insulating materials cannot be cast, rolled, drawn, and machined like the metals, which forces the adoption of other methods, often special for each case. Moreover, insulation is an inactive portion of the apparatus, playing a negative part in the generation of power, and the space occupied is considered as wasted. Hence, the designer tries every means possible to reduce the insulation space and allow more room for his copper and steel.

Cotton in the form of cloth, tape, or wire covering has the property of easy application and good tensile strength. It is, however, lacking in high dielectric strength. So the cotton is used as a supporting medium for materials high in dielectric strength, but poor mechanically. Such materials are varnishes, shellacs, asphalts, and resins. They all possess high dielectric strength and can be applied in the form of a liquid which turns to a solid after application. Each of these materials has properties applicable to certain definite conditions. Varnishes and shellacs contain a considerable percentage of volatile solvents, which must be driven off. Hence, these materials are seldom used to impregnate coils, as the volatile solvents would have difficulty in working their way out from the center of a coil, and even if this were successfully accomplished, would leave the coils full of pores where the solvents had worked their way through.

This leaves the asphalts and resins as the materials available for impregnation. They can be liquified by heat, and forced into

the coil in that condition. They harden on cooling, forming a solid coil, free from porosity and volatile solvents. As a result, the wires are held firmly in place, heat is assisted to pass from the inside of the coil to the atmosphere, and the life of the coil is materially lengthened. The compound fills the porous covering of the wires and any small spaces in the coils, thus increasing the dielectric strength and preventing abrasion. Moisture cannot soak into the coil and cause short-circuits. If the impregnating material used is suitable, it will resist the influence of high temperatures, acids and other corrosive agents.

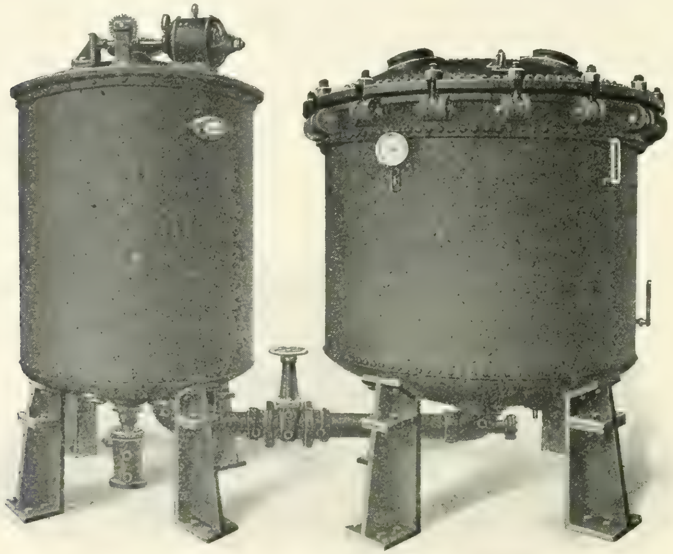

FIG. I—COMMERCIAL FORM OF IMPREGNATING APPARATUS
J. P. Devine Co., Buffalo, N. Y.

In proof that these results are actually obtained, heat runs have been made over and over again on duplicate coils, some impregnated and some not. In every case the unimpregnated coils have shown a temperature rise of from five to twenty percent higher than the impregnated coils. Ageing tests have been made at temperatures considerably above those occurring in service. It was found that the plain cotton covering was ruined at comparatively low temperatures while the impregnated coils showed absolutely no effect. Tests for varying periods at temperatures above the melting point of the impregnating compound did not injure the insulation of impregnated coils, but caused the impregnating com-

pound to run out. On re-impregnation, the coil was as good as new. Impregnated coils have been kept under water continuously and insulation resistance measured from copper to ground, care of course being taken to protect the leads. At the end of several weeks no decrease was observed. A specific instance which may be cited is that of a direct-current motor with impregnated field and armature coils, which, as a test, was run under a stream of water for several days, shutting down every night to permit the water to soak into the windings. No break-downs or trouble of any kind occurred.

PROCESS AND APPARATUS

A commercial form of impregnating apparatus is shown in Fig. 1. The general principles of the process and details of the apparatus used are illustrated by the diagram Fig. 2. Coils are first thoroughly dried, either in a separate oven, or in the impregnating

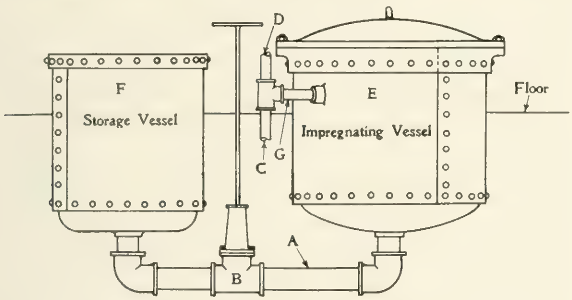

FIG. 2—DIAGRAM OF STANDARD IMPREGNATING APPARATUS

tank. They are placed in the tank *E* and heat is applied until tank and coils reach a temperature at which the impregnating compound is thoroughly fluid. The air in the tank is then exhausted by a vacuum pump through the pipe *D*. After the vacuum has drawn the last traces of moisture from the coils, the valve *G*, connecting to the vacuum pump, is closed and the compound, previously heated to a thoroughly liquid condition in the storage tank *F*, is drawn into the impregnating tank *E* through the valve *B* and connecting pipe *A* by means of the vacuum in the impregnating tank *E*. When the coils are thoroughly covered, the valve *B* is closed and air pressure admitted to the impregnating tank through the pipe *C*. This condition is maintained until the coils are impregnated. The valve *B* is then opened, and the gum is forced back into the storage tank *F* by means of the air pressure in *E*.

Impregnating apparatus is now designed and manufactured by several companies. The different forms are all based on essentially

the same principles and differ only in mechanical design. Some of the essential features for successful operation are as follows. The pipe *A* connecting the storage tank and impregnating tank must be of large cross-section, free from obstructions of any kind, steam heated, and heavily lagged. The same remarks apply to the gate valve *B*. For convenience this valve usually has an extended stem that can be operated from the floor level. The vacuum and air pipes, *C* and *D*, should enter the tank through one opening, as each opening weakens the tank and increases danger of leaks. A smaller pump will be sufficient if the vacuum is drawn through a condenser than if the pump is required to handle the uncondensed vapors. The air furnishing the pressure should be thoroughly dried, preferably by a calcium chloride receiver, before entering the tank.

The details of the process depend on the nature and melting point of the gum and on the amount of pressure available. The pressure generally used is 60 to 80 pounds per square inch. The temperature should be high enough to make the gum very fluid, but should not be so high as to injure either the gum or the insulation of the coil. The length of time required under vacuum and pressure can only be determined by trial. With a very fluid gum, high temperature and pressure, a half-hour under pressure may be sufficient; under adverse conditions, ten hours may be required. Usually from one to six hours vacuum will dry any ordinary coil provided it is thoroughly heated.

It is in these details that the skill of the operator is exercised. The way the coils are placed in the tank, the fluidity of the gum, which varies from day to day, the time of drying, all require that accuracy of judgment which can be reached only after long experience. Judgment must also be used in designing coils so that a path is always left for the gum to enter. Varnished materials, paper, pressboard, fiber and wood are practically impervious, even to the most fluid of the gums. Cotton covering and untreated cotton or linen cloth are readily penetrated by the gum. If there is a continuous pathway of these materials, or of capillary spaces, to the center of the coil, the wires may be as closely spaced as desired without preventing thorough impregnation. Large spaces between wires or sections of a coil are almost impossible to fill. If they are entirely inside the coil, there is no way for the gum to enter except through capillary spaces too tiny to admit any large amount of gum.

If they are near the outside the gum will flow out as readily as it flowed in, and before the coil can be cooled will have all run out.

MATERIALS

The selection of the material to be used for the impregnating compound is both important and difficult. The melting point must be high enough so that the gum will not flow out at operating temperatures and low enough so that the temperature available in the impregnating apparatus will render it thoroughly fluid. Degree of hardness is a matter of personal judgment. Gums can be obtained all the way from "dead soft" to very brittle. For best results the

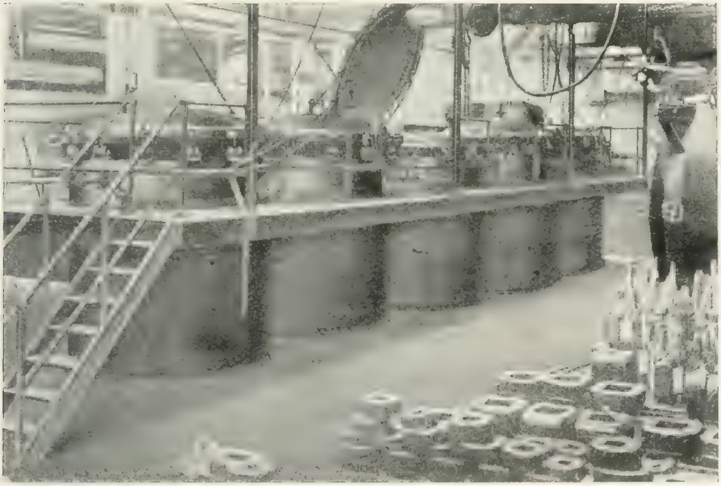

FIG. 3—BATTERY OF STANDARD SIZE IMPREGNATING TANKS

gum should not be "short," that is, crumbly, nor should it have any tendency to "flow cold." It should be exceedingly fluid at a temperature not over 100 degrees F. above its melting point, and it should not soften much at a temperature 35 degrees F. below its melting point. It is obvious that the gum must be able to stand continuous heating to a point of greatest fluidity without injury. Many gums, especially those artificially compounded, contain a considerable proportion of light gums or oils, that tend to distill off with heat. When such distillation occurs the manufacturers usually furnish a "flux" to replace that part which distills off, but the less the distillation, the more uniform are the results obtained.

As a class, asphalts are best suited for use as impregnating gums. There is a large number of different asphalts possessing various characteristics, some good and some bad. Careful tests covering long periods have eliminated one after another until the list of suitable gums has been reduced to a few, differing from each other in hardness, toughness and melting point, but all possessing good penetrating power and ability to stand continuous heating. In some cases the gums may be found to have the particular degree of hardness and melting point desired. In other cases compounding may be necessary.

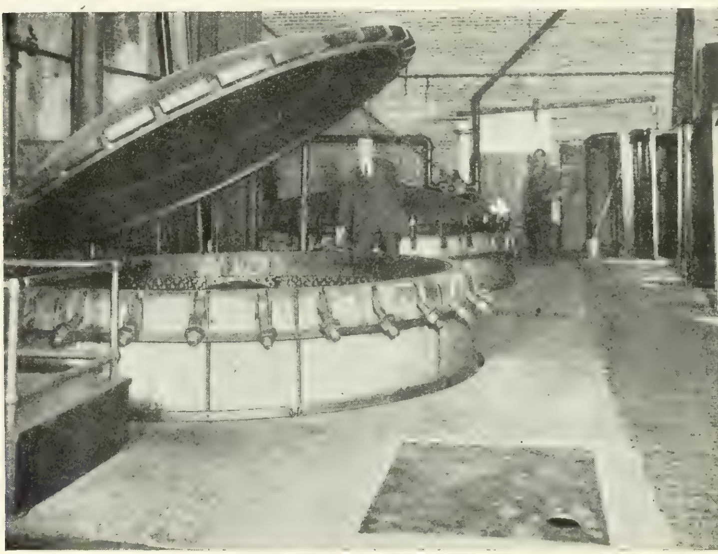

FIG. 4—IMPREGNATING TANKS
Largest capacity ever built. Of sufficient size to handle the largest turbo-generature armature coils. View taken from second floor level. Racks for loading the coils in the tanks are shown at the right of the illustration.

These gums and compounds come from a great many different sources. Impregnating compounds designed for the purpose are made with almost any degree of hardness and any melting point by most of the insulating varnish makers. The gums themselves may be divided into two main classes:—manufactured gums and natural gums.

Manufactured Gums—The manufactured gums are the product of distillation and oxidation of crude petroleum, from certain dis-

tricts of Pennsylvania, Texas, California, and a few other isolated districts. The light oils, including gasoline and naptha, lubricating oils, etc., are all in turn driven off, leaving in the still a thick viscid mass quite fluid at a temperature of several hundred degrees. Air is then forced through this mass, hardening it and removing final traces of the light oils. The quality of the product depends on the kind of oil used, the temperature and duration of the distillation and the temperature and duration of the blowing period. Some of these manufactured asphalts or "petroleum residuums," as they are called, are very brittle, others are soft and crumbly, and the melting point is apt to vary from one run to another. One serious defect that has been found in some samples is a considerable proportion of volatile oil remaining in the gum after distillation. These

FIG. 5—VIEW AT LAKE TRINIDAD

Lake Trinidad covers about 114 acres, is nearly circular in outline, and a little less than half a mile in diameter. The surface is hard enough to bear the weight of carts and mules, provided they are kept in motion. About 100 000 tons of asphalt are removed annually without appreciably diminishing the supply. It has been impossible to find the depth of the lake, though borings of several hundred feet have been made.

residuums, however, furnish the principal source of supply for the softer gums. Some very fine, stable materials are turned out by this process, preferable in many ways to the natural gums.

Natural Gums—Natural asphalts are mined in many parts of the world. The best known source is the vast asphalt lake on the Island of Trinidad. (See Fig. 5.) This immense deposit has furnished paving material for streets in most cities of the world for many years, and yet its contents are scarcely diminished. In the

last few years its use is being largely supplanted by the petroleum residuums, but for a long time Trinidad asphalt was the standard of the world. Most of the other asphalts are hard and of high melting point. Some are so refractory that they will not melt at any temperature. *Elaterite*, for example, cannot be melted and has no known solvent. Acids do not affect it, but extreme heat gradually causes disintegration. *Gilsonite* is the best known of the hard natural asphalts. It melts at 160 to 200 degrees C. and is very hard and brittle. This gum is frequently used to harden up the softer or lower melting point gums and it forms the base for most baking japans. *Manjak* is another well-known hard natural asphalt. The Barbadoes *Manjak* which melts at over 200 degrees C. is very hard and tough. It is difficult to mix this gum with other compounds, owing to its high melting point and certain other peculiar characteristics. When properly compounded, however, it adds very desirable characteristics to the product.

Oil-Proof Compounds—All asphalts are more or less soluble in oil. Hence, they are not entirely satisfactory for use in oil insulated transformers. The oil softens and partially dissolves the gum, which then gradually flows to the bottom of the tank, forming a soft, sticky mass. Although the oil undoubtedly flows into the spaces in the coil left by the gum, most of the benefits obtained by impregnating are lost. For this service oil proof compounds have been developed by several different manufacturers. They are all alike in principle, being composed of resinous gums, compounded in such a way as to give the necessary hardness, melting point and penetrative power. Some of the compounds contain a small proportion of castor oil or linseed oil, or some other vegetable oil. The resinuous gums used come generally from Asiatic ports, China, India, Phillipine Islands and Korea. They are excretions from trees belonging to the same family as the pine, from which we get our common resin. Some gums are obtained by tapping the trees, collecting the sap and then distilling off the liquid part. Others are found in lumps attached to the bark of the tree, or in the ground around the roots. Others still are "fossil" gums, dug from the ground, where they have been buried for many years, the origin, however, being the same in each case. *Manilla, kauri, dammar, sandarac, climi, Venice turpentine, Burgundy pitch* and *Canada balsam* are among the best known. A complete list would comprise some thirty or forty other gums. Some are soluble in oils, some in alcohol, turpentine, ether, chloroform, acetone, etc. Some are in-

soluble in about everything except linseed oil. The melting point varies all the way from *Venice turpentine,* which is a thick, syrupy liquid, to that of *zanzibar* and *angola,* which melt at about 575 degrees F. Hardness is another variable, *amber* being the hardest known resin.

Preparation of Oil-Proof Compounds—The preparation of the compound is a difficult and often expensive operation. The gum of highest melting point is put into a large kettle over a slow fire of either gas or coke and heated gently until thoroughly melted. Dense fumes are thrown off during this operation. Then the other gums, sometimes previously melted in another kettle, are added and the mixture is vigorously stirred. Heating must be continued until the mixture is thoroughly fused and perfectly mixed. Overheating changes the characteristics and generally ruins the whole mixture. The process is somewhat analogous to varnish making and requires the same skill and long experience.

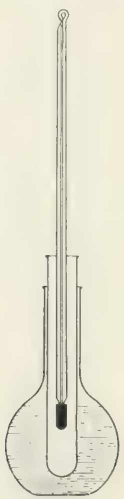

FIG. 6 — APPARATUS FOR DETERMINING MELTING POINT OF IMPREGNATING COMPOUNDS

Application—The use of an oil proof impregnating compound is much more difficult than of the asphaltic compounds. Constant care and watchfulness are necessary for consistent results. The melting point and other characteristics must be tested at frequent intervals and new materials added in such proportions as are necessary to correct changes that have taken place. Temperature, pressure and vacuum must all be watched very closely. When these precautions are taken under the supervision of men trained in the work, the results obtained improve the electrical and mechanical properties of the apparatus thus treated many fold.

METHODS OF TESTING

To determine the characteristics of a new sample and to keep the condition of the compound in the tanks at maximum working efficiency it has been necessary to devise several new methods of testing. A description follows of methods that have been in use for some time. The results are, of necessity, arbitrary, but if these methods or other equivalent methods are universally adopted the comparative value of the results will be correct.

Melting Point—Asphalts and resins require a considerable dif-

ference in temperature to pass from a solid to a liquid state. A compound may be solid at 90 degrees C., start to soften at 95 degress C., and not be thoroughly liquid at 150 degrees C. It is necessary, therefore, to make an arbitrary definition of melting point. This is spoken of as the "Dropping Point" and is taken as the temperature at which the first drop of gum falls from the bulb of a thermometer, the gum being molded on the thermometer bulb and the thermometer and gum heated at a uniform rate. It has been found by test that the melting point thus obtained must be taken under absolutely uniform conditions in order to get consistent results. A standard form of apparatus is shown in Fig. 6. The best practice is as follows:—Use a chemical thermometer with a bulb 1/8 inch in diameter and a quantity of gum equal to a ball 3/16 inch in diameter. After the thermometer has been heated slightly, mold the gum on the thermometer in a 20 mm. test tube and place the test tube in a 100 cc. flask, the bottom of the test tube coming to just 1/2 inch above the bottom of the flask. Fill the flask to the bottom of the neck with glycerine. The top of the gum as molded on the thermometer should be just on a level with the top of the glycerine. Heat the apparatus uniformly at the rate of five degrees C. per minute. The gum will soften and a drop will eventually detach itself and fall. The temperature of the thermometer at the time when this occurs should be taken as the melting point.

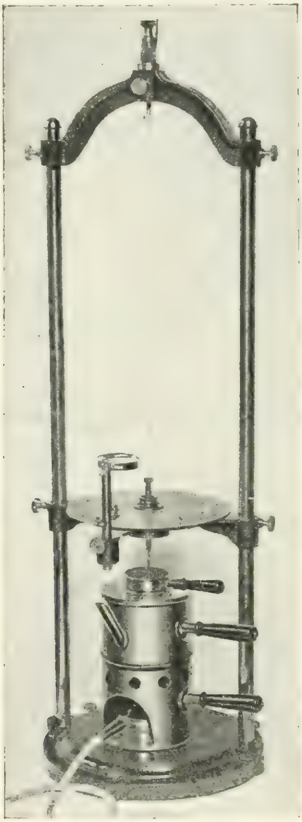

FIG. 7—DOOLITTLE VISCOSIMETER
Eimer & Amend, N. Y. City.

Fluidity—Fluidity at temperatures above the melting point may be measured by a Doolittle viscosimeter, as illustrated in Fig. 7. This apparatus consists of a smooth brass cylinder suspended by a wire, the cylinder being surrounded by a bath of the melted gum.

The cylinder is given a rotating tendency by means of a definite amount of torsion in the wire, and the fluidity is taken as proportional to the retardation effect of the gum on the cylinder, measured in angular degrees. The gum should be heated uniformly to a point of good fluidity and held exactly at this point throughout the test. An electrical heater is the most convenient. The most accurate results can be obtained by plotting a curve of fluidity (inversely proportional to degrees retardation) vs. temperature, starting at the lowest fluid point and extending up to 200 or 225 degrees C. A typical fluidity curve, obtained from a test of a standard impregnating compound, is shown in Fig. 8.

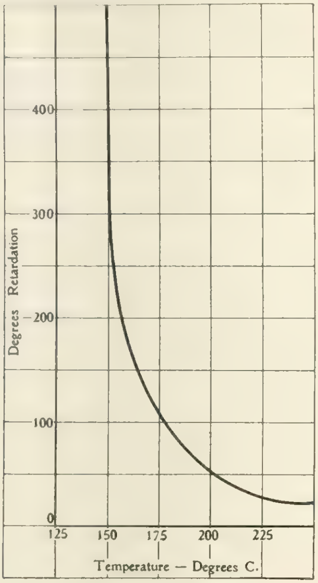

FIG. 8—FLUIDITY CURVE

Penetrative Power—A quick test for penetrative power consists in determining the time required to penetrate a single layer of filter paper, preferably of medium grade, the filter paper being held below the surface of the melted compound. The time taken is that required for the first particle of the gum to penetrate the filter paper, as indicated by the color of the paper turning from gray to black. For best results the paper should be stretched tightly across the end of a thin-walled hollow metal cylinder one inch in diameter. The gum should be heated uniformly throughout to a fixed temperature, the scum pushed back from the surface, and the filter paper quickly plunged to a depth of one inch below the surface. The inner surface of the filter paper is then viewed through the cylinder and the time required for penetration noted. Penetration curves for several impregnating compounds are shown in Fig. 9.

Hardness—Hardness may be measured by means of a "penetration machine" of which there are several types on the market. A flat ended needle of definite diameter is forced into the gum by a definite weight and the distance the needle penetrates in a measured time is taken as the degree of hardness. In practice, however, this test is often found to be unnecessary.

Effect of Heat—The test for effect of continuous heating is the most difficult and the least satisfactory. If the gum contains no drying oil (linseed, for example) a small quantity heated in an air oven at a measured temperature for a given length of time, will give fairly accurate results. The temperature in this test must be kept extremely constant and measured very accurately. Chemical analysis may give an indication of what may be expected, provided there

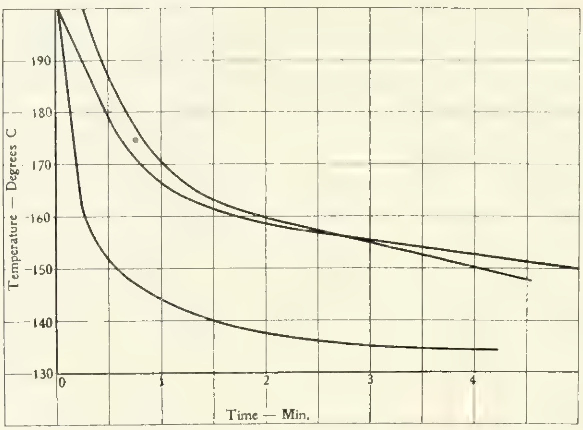

FIG. 9—CURVES SHOWING RELATIVE PENETRATIVE POWER OF SEVERAL IMPREGNATING COMPOUNDS

is sufficient data at hand for comparison with gums of known characteristics. The only entirely satisfactory test is a long continued trial under service conditions. Such a test, which is both difficult and expensive, should always be made before the adoption of a new material.

MOTOR-GENERATOR SETS OF 3 000 KILOWATTS MAXIMUM CONTINUOUS RATING

DAVID HALL

FOR the transformation of electrical energy from one form to another, the motor-generator offers the greatest flexibility. As there is no electrical connection necessary between the motor and the generator, the two machines may be entirely different as to the kind of current supplied and delivered. Problems often arise in practice for which the motor-generator set, on account of this inherent characteristic, offers the most effective solution. One of the most common applications of the motor-generator set is for the transformation of alternating current of high voltage to direct current of low voltage, at the end of long transmission lines. Here a natural variation in voltage may occur, or there may be necessity for regulating the alternating-current voltage independent of the direct-current conditions. A distinctive feature of such application is that the alternating-current and direct-current voltages may be regulated and controlled independently, thus giving a flexibility which cannot be so easily obtained in any other manner. The speed of a motor-generator set can also be made comparatively high, thus reducing the size and weight for a given output and also minimizing the floor space required. A good feature of the motor-generator is the ease with which such a set may be started from either the alternating-current or direct-current end.

With the increased demand for motor-generator sets, especially for railway application, there has been a gradual increase in the output which can be satisfactorily obtained from such sets. Only a few years ago it would have been considered impossible to have furnished motor-generator sets operating at as high a speed as 300 r.p.m. and capable of delivering satisfactorily 4 000 kw in direct current. However, with the improvements in general design as regards commutation, it is now possible to make railway generators of such outputs, which operate even better than the slow-speed machines of a few years ago. The machines of later design will stand more abuse and heavier overloads, and even when the circuit-breakers open under excessive load there is no tendency to flash over at the brushes. These results have been accomplished by reason of a better understanding of the controlling factors in commutation and by

the introduction of improvements which automatically give the machine the desired characteristics.

A number of motor-generator sets of recent design which have been constructed and tested are shown in Figs. 1 and 2. The direct-current machines of these sets are rated on a maximum continuous basis of 3 000 kw, 600 volts, 300 r.p.m. They will carry this rated load continuously with a temperature rise well below 40 degrees C., and will deliver 4 000 kw for several hours without injury. The entire range of operation, from no-load to a load of 4 000 kw, is obtained with good commutation and with one setting of the brushes. The machines also permit adjustment of voltage throughout a wide range without affecting the commutation.

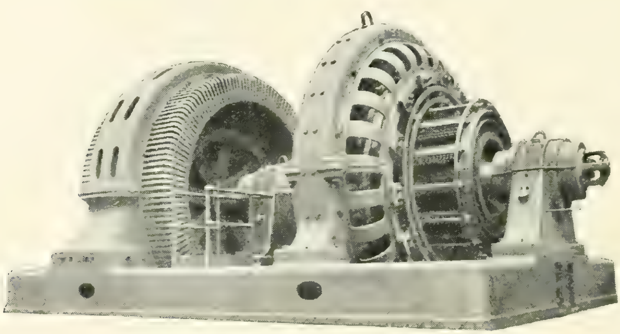

FIG. 1—GENERAL VIEW OF MOTOR-GENERATOR SET
Maximum continuous capacity, 3 000 kw. 600 volts, 300 r.p.m.

The sets are driven by 6 300-volt, 50-cycle, three-phase synchronous motors. These motors have open armature slots with form-wound strap coils braced against possible stress due to short-circuit or other disturbance. To prove the adequacy of the bracing, the armature of one of the machines was subjected to a sudden short-circuit at normal voltage without any perceptible movement of the windings. The rotors are of the type which has become fairly well standardized for machines of moderately high speeds, separate laminated poles being dovetailed to a steel spider. The strap-on-edge field coils are clamped between the spider and the pole tips on the sides, and between suitable coil supports on the ends of the poles. The rotor* is provided with a squirrel-cage starting wind-

*See "Self-Starting Synchronous Motors" by Mr. Jens Bache-Wiig in the Journal for June, 1909, p. 347.

ing similar to that of an induction motor, so that the set can be started from the alternating-current end by applying low voltage to the armature. While these sets are large to be started in this way, if the capacity of the system on which they will be operated is sufficient this method of starting is justified.

While a design employing two bearings is possible for almost any size of machine, the use of three bearings, as employed in the present case, offers decided advantages as regards ventilation and ease of handling. The shaft is in two parts, the flanges being forged solid with the shafts, the two parts of the shaft being coupled between the center bearing and the direct-current armature. This arrangement facilitates handling, shipping and erection.

The base is divided into two halves through a center line parallel to the shaft, an arrangement employed with a view of facilitating handling in shipment. The two halves are aligned and centered by means of keys and dowels and are supplied with heavy bolts for holding them together.

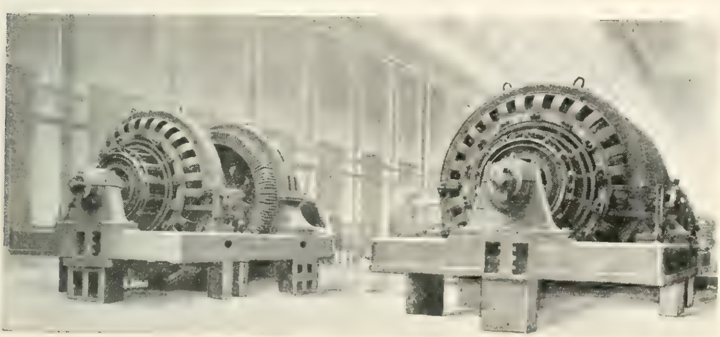

FIG. 2—LARGE MOTOR-GENERATOR SETS ON TEST

In general it is advisable to supply sets above 1 000 kw with water-cooled bearings. In the present case the bearing shell, which is separated from the pillow block, is supported by the latter at the center, which insures accurate alignment. Oil rings are supplied in the usual manner, while provision is made for gravity feed when desired.

On large sets it is also the general practice to provide a special shaft extension on which to mount a pulley for use in driving the armature in case it ever becomes necessary to turn down the commutator. However, with improved methods for obtaining good commutation, it is seldom necessary to resort to this expedient.

Uniform wearing of the commutator is insured through the provision of a standard oscillator of the ball and race type, which is very simple in construction and entirely free from any external complications or connections. An over-speed device, which is easily adjusted to operate at any desired r.p.m., prevents the set from attaining a dangerous speed.

Two sets were recently tested at full-load and over-load by the customary method of loading back one set on the other, supplying the losses electrically. They are shown in Fig. 2 erected on the testing floor. In this case the losses were supplied to the direct-

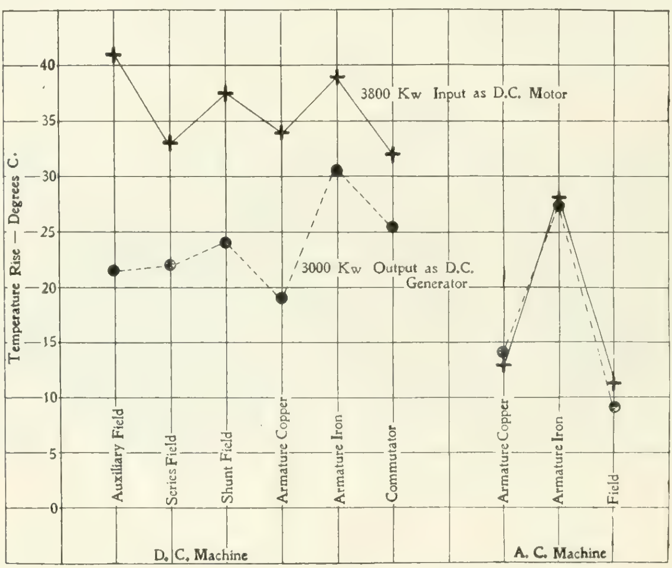

FIG. 3—CHART SHOWING TEMPERATURE RISES OF VARIOUS PARTS OF 3 000-KW MOTOR-GENERATOR SET

The method used in testing these sets made it possible to load the alternating-current motors and the direct-current generators of two sets simultaneously, one direct-current machine acting as a generator with normal full load and the other direct-current machine operating as a motor with 25 percent overload. The losses were supplied electrically from a separate circuit.

current motor. By so doing the tests were made simultaneously at full-load, on both alternating-current machines, at 3 000 kw output from the direct-current generator and at 3 800 kw input to the direct-current motor. The extra 800 kw input represents the 320 kw losses of one set at full-load combined with the losses of the other

set at 25 percent overload and the losses in the circuits connecting the two sets.

As shown in Fig. 3, the temperature rises in degrees C. of the set which was delivering a direct-current output of 3 000 kw for six hours were as follows:—

Direct-current armature copper, 19 degrees C.; armature iron, 30.5; commutator, 25.5; shunt field, 24; series field, 22; auxiliary field, 21.5.

The temperature rises of the set which was receiving a direct-current input of 3 800 kw for six hours were as follows:—

FIG. 4—ARMATURE OF DIRECT-CURRENT GENERATOR OF 3 000 KW MOTOR-GENERATOR SET

Direct-current armature copper, 34; armature iron, 39; commutator, 32; shunt field, 37.5; series field, 33; auxiliary field, 41.

Alternating-current armature copper, 13; armature iron, 28; field, 11.

The low field and armature winding temperatures given above and the low exciting voltage required indicate the ample margin for operation at the low leading power-factor for which the synchronous motors are designed. The results of commutation tests when tripping the circuit breaker at loads of 3 000 and 4 000 kw were very satisfactory, there being no indication of a tendency to flash, or of any other disturbances.

The over-all efficiency of the set is 90.5 percent, i. e., when the generator is delivering 3 000 kw output, the motor will require an input of 3 320 kw, which shows a total loss of 320 kw. Of this, 60 kw is taken up in windage and friction. One set complete weighs about 200 000 pounds. This gives a weight of 65 pounds per kw output.

Two of these sets have recently been shipped from the works of the Electric Company at East Pittsburg to the Rio de Janeiro Tramway, Light & Power Company, of Brazil, South America.

A NEW METHOD OF LABELING TUNGSTEN LAMPS

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THE general introduction of the tungsten lamp has brought into prominence many factors which were of minor consequence in connection with carbon lamps. The higher candle-power in which the lamps can be made, the higher intrinsic brilliancy of the filament and the whiter color of the light have all brought forward problems in the use of lamps which had scarcely been considered in connection with carbon lamps, but have been the principal factors underlying the recent impetus which has been given to illuminating engineering.

The economic question is put on a new basis. The cost of current for operating the tungsten lamp is low, while the first cost for lamps is usually high in comparison with the carbon lamp. Even in the matter of first cost, the comparison between carbon and tungsten is not a simple one. For instance, five 16 c-p carbon lamps may be replaced by one 80 c-p, 100 watt tungsten lamp. The latter, with a life of 1 700 hours, will practically equal in life three successive lots of 3.1 watts per candle carbon lamps having a life of 450 hours. Hence, one tungsten lamp would be the equivalent of about 15 carbon lamps, and the one tungsten lamp would cost about half as much as the fifteen carbon lamps. The first cost of wiring, sockets and reflectors would also be considerably less. It follows, therefore, that in cases where one large tungsten lamp can be used to replace several carbon lamps of the same aggregate candle-power, there would be a considerable saving in the cost of installation and in the lamps themselves, as well as a large saving in the cost of power, as the tungsten lamp would require only 40 percent of the current taken by carbon lamps.

The operating cost for electric lighting depends principally upon two factors—the cost of lamp renewals and the cost of current. A carbon lamp whose price is 20 cents, will consume normally during its life several dollars worth of current at ordinary central station rates. Consequently, one could well afford to pay considerably more for the lamp itself, or in other words he could well afford to

use lamps of relatively short life, provided even a small percentage of saving in current could be secured. Obviously, the elements in the problem change with the change in the price of current.

With the tungsten lamp, on the other hand, the cost of the lamp itself is considerably higher than that of the carbon lamp and the cost of current which it uses is much less. The relation between current consumption and lamp life is, therefore, on a somewhat different basis from that of the carbon lamp on account of the relation between the first cost of the lamp and the current which it uses.

When tungsten lamps were placed upon the market the ordinary designation of the lamps was in watts instead of candle-power, as had been the custom and is now the case with carbon lamps. As it was understood, however, that the lamps were rated at 1.25 watts per candle, it was an easy matter to determine the candle-power corresponding to a given number of watts. The tungsten lamps were marked or labeled with a single voltage which was the normal voltage at which the lamps were to be operated when the efficiency was 1.25 watts per candle.

It is well known that the life of a given lamp is increased if the lamp be operated at a voltage below rating. This, of course, involves a reduced candle-power and a higher power consumption per candle-power. The most economic voltage at which a given lamp can be operated depends in a very large measure upon the cost of power per kilowatt-hour. Nevertheless, at the time of its introduction it was considered best to label the tungsten lamp with a single voltage adapting it for a single efficiency and a single length of life.

As experience with tungsten increased and the many processes were perfected it was found that the life of the lamps depended upon two elements, the watts per candle and the diameter of the filament. The 25 watt lamp at 1.25 watts per candle, with its small filament, has a much shorter life than the 100 watt lamp at the same efficiency, and the same characteristic difference in life was observed in lamps of all sizes. It was found also that for any given cost of current per kilowatt-hour there was a corresponding voltage and efficiency resulting in an average life which gave the most economical result. The actual life of the 25 watt lamp, which is about 500 hours at 1.25 watts per candle, was found to be too short and that of the 250 watt lamp, which is 1 800 hours at the same

efficiency, was found to be too long for the most economical service at the ordinary commercial cost for current.

To overcome this inconsistency the lamp manufacturers have recently decided to make a radical change in the method of labeling tungsten lamps whereby the lives of all lamps would be the same under like conditions. To place a method of labeling of this kind in use it was necessary to accumulate a great mass of data on each type of lamp from all laboratories making extensive tests on these lamps. This data had to be carefully studied, and the lives of the various lamps at the various efficiencies tabulated and then a determination made as to the most economical lamp to use at the various costs for current and the results tabulated and a labeling method worked out. During the tabulation of the data it was found that the average life of the 25 watt lamp at 1.25 watts per candle was shorter than the 500 hours given in the lamp data books; the life of the 40 watt lamp at 1.25 was a little longer than the 800 hours, given in publications, and the lives of all larger lamps was much longer. It was also found that many users of tungsten lamps, on finding the lives of 25 watt lamps shorter than they had expected, changed the voltage of all tungsten lamps ordered to two, three, and sometimes more, volts above the line voltage, in order to increase the life of the short-lived 25 watt lamp. This practice of burning tungsten lamps under voltage was a step in the right direction for the short-lived 25 watt lamp, but it was a backward and expensive step for the user of the lamps of higher capacity and longer life, the increased current consumed per candle-power making the consumption of current far offset any reduction in cost of renewals due to longer life.

To provide for all of the peculiar conditions met with it was decided to adopt the three-voltage label, so satisfactorily used on the metalized or Gem filament lamp, and rate the lamps at top voltage from 1.33 watts per candle for the 25 watt lamp, to 1.15 watts per candle for the 250 watt lamp with all lamps giving an average life of 1 000 hours at the top voltage efficiencies.

Like the metalized filament lamp label the voltages are marked in steps of two volts each, the middle voltage being two volts below the top, with a corresponding increase in the watts per candle and life and a decrease in the total watts and the candle-power. The bottom voltage is two volts below the middle or four volts below the

top voltage, with corresponding changes in watts per candle, life, total watts and candle-power, all as shown in Table I.

These efficiencies and lives provide lamps which are the most economical to use at all commercial costs for current. For the higher costs of current, say above approximately six cents per kilowatt-hour, the top voltage lamps are the most economical to use, as the

TABLE I.

Watts.	Top Voltage.		Middle Voltage.		Bottom Voltage.	
	w.p.c.	Life.	w.p.c.	Life.	w.p.c	Life.
25	1.33	1000	1.39	1300	1.45	1700
40	1.25	1000	1.30	1300	1.35	1700
60	1.20	1000	1.25	1300	1.30	1700
100	1.20	1000	1.25	1300	1.30	1700
150	1.20	1000	1.25	1300	1.30	1700
250	1.15	1000	1.20	1300	1.25	1700

cost for lamp renewals plus the cost of current is a minimum. For somewhat lower costs of current the middle voltage lamps are the most economical. Where the price of current is quite low the bottom voltage lamps are the cheapest to operate.

For example, in the case of a 110 volt circuit, if a consideration of the above factors shows that it is advisable to operate the lamps at high efficiency, lamps should be used bearing labels indicating a top voltage of 110; middle voltage, 108, and bottom voltage, 106. On the other hand, if the cost of current is very low, the 110 volt circuit should be provided with lamps marked 114-112-110 volts.

These economical points are based on actual engineering facts and, barring the risk of mechanical breakage in use, can be relied upon. In most lighting installations, there is the risk of mechanical breakage which is not decreased by using lamps at the bottom voltage. In general, it is safe to install the top voltage lamps except in cases of extreme low cost for current.

APPLICATION OF THE OSCILLOGRAPH IN STUDYING THE OPERATION OF MERCURY RECTIFIERS

YASUDIRO SAKAI

THE usefulness of the oscillograph is admirably illustrated in its application to the study of mercury rectifier phenomena. The distortion of wave-forms, both e.m.f. and current, due to the action of the rectifier makes the vector calculations applied to ordinary alternating-current phenomena very awkward. Ordinary meters indicate integral values, whatever the wave-form, while the oscillograph shows every detail of wave-form; hence it is often found that the true meaning of the indications of the ordinary meters is brought to light only when the nature of the wave-form is disclosed by the oscillograph.

RECTIFIER-HYDRAULIC ANALOGY

The rectifier in its usual form consists of an hermetically sealed glass bulb containing mercury and mercury vapor. The bulb is provided with three terminals, two positive leads or "anodes" and one negative lead or "cathode." The former terminate inside the bulb with electrodes made of graphite or some other conducting substance which will not amalgamate with the mercury and which serves to conduct the current from the external circuit to the vapor inside. The cathode is formed by mercury in the bottom of the bulb, from which current is conducted to the external circuit by a platinum electrode sealed in the glass. The positive leads are connected to terminals of the secondary winding of a transformer, and the negative lead is connected, through a reactance coil, to the positive side of the load circuit. The negative side of the load circuit is connected to the middle tap of the secondary winding of the transformer. The rectifier bulb has a peculiar property of conducting electricity in one direction only, i. e., from anode to cathode, under ordinary working conditions; thus the bulb may be called an electrical check valve and its action of rectifying to direct current can well be illustrated by the analogy of the action of an ordinary reciprocating hydraulic pump. Fig. 1 shows diagrammatically the essential features of a rectifier system for charging a storage battery, and of a pump system for forcing water into a tank; their corresponding parts are side by side and lettered similarly to make

the analogy clear. The pressure produced inside the cylinder of the pump by the reciprocating action of the piston corresponds to the alternating e.m.f. induced in the secondary winding of the transformer. During the period when the terminal P_1 is positive, the valve action of the bulb will allow current to flow from the positive lead P_1 through the vapor inside the bulb to the negative terminal K only. The terminal P_2 being negative, the check valve action will prevent current flowing to that terminal and as long as it is of negative polarity, it will remain idle. But as soon as the induced e.m.f.

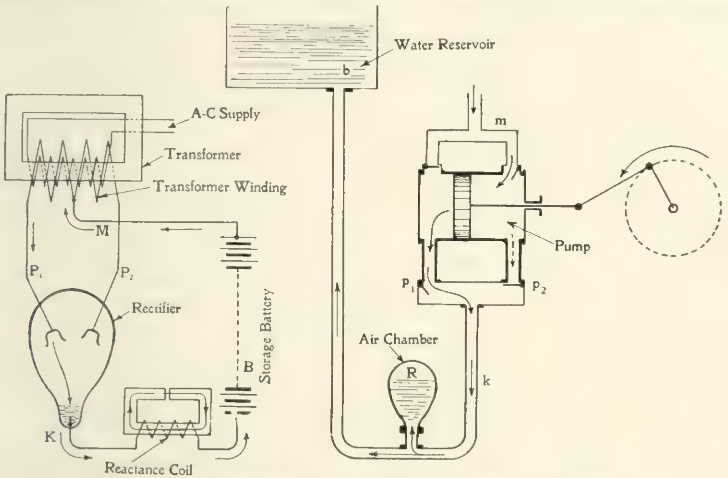


FIG. 1—DIAGRAM SHOWING THE ANALOGY OF THE RECTIFIER AND PUMPING SYSTEM

reverses, i. e., when the terminal P_2 becomes positive, the current will begin to flow from the lead P_2 through the mercury vapor to the cathode K and at the same time current will cease to flow from the other lead P_1, because this terminal is now of negative polarity. In this way the action of the electrical valve is repeated cycle after cycle. The same check valve action would be present at the cathode were it not that the current flow, when once started, holds the valve open.

Comparing this valve action to that of the pump system, it will be seen by referring to Fig. 1 that when the piston is moving toward the head end, the valve p_1 will open and allow the water in the cylinder to flow into the pipe k, but the valve p_2, the pressure upon which is inward, will remain closed and prevent water from flowing back into the cylinder. But as soon as the movement of the piston reverses, the valve p_2 will open and perform the same duty as did

the valve p_1 in the previous case. From this it will be seen that, although the pressure generated inside the cylinder is of a reciprocating nature, the pressure in the pipe k is uni-directional and the direction of flow of the water is always the same regardless of the direction of movement of the piston. In an analogous manner then, the alternating e.m.f. induced in the secondary winding of the transformer is rectified and causes the current to flow in the wire K in one direction only.

The flow of water in the pipe K, though uni-directional, is very fluctuating. As the piston approaches the end of its travel, the pressure in the cylinder falls and consequently the flow of water decreases, ceasing entirely at the moment of reversal. The same sort of fluctuation of electric pressure and current takes place also in the rectifier system. To smooth down the fluctuation of the flow of water an air-chamber is provided in the delivery line of the pump, and a reactance coil is similarly inserted in the direct-current circuit of the rectifier system. The operation of the reactance coil will be discussed more fully in connection with the study of oscillograms taken from the various parts of the rectifier circuit. The analogy cited above should not be carried too far; for instance, there is a discrepancy in that the air-chamber stores up water under pressure, while the reactance coil does not store up current, but builds up a magnetic field, thereby storing up electrical energy. Moreover, while the electric current flows in a complete circuit, the water does not.* A series direct-current arc lamp system employing a mercury rectifier outfit and a constant current regulator are shown diagrammatically in Fig. 2.

OSCILLOGRAMS FROM VARIOUS PARTS OF RECTIFIER CIRCUIT

Curves *1* and *2*, Fig. 3, represent the e.m.f. wave-form in the circuit between the middle point M, Fig. 2, of the secondary winding of the regulating transformer, and one of the positive leads, P_1 of the rectifier bulb of an arc-lighting rectifier system, this being the

*See also "Cooper-Hewitt Mercury Rectifier," by P. H. Thomas, The Electric Journal, July, 1905, p. 397.

"Constant Current Mercury Arc Rectifier," by C. P. Steinmetz, Trans. A. I. E. E., June, 1905, p. 371.

"Some Fundamental Characteristics of Mercury Vapor Apparatus," by P. H. Thomas, Trans. A. I. E. E., May, 1906, p. 601.

"Commercial Development of the Mercury Rectifier," by Frank Conrad, N. E. L. A., Washington, D. C., June, 1907.

"The Mercury Rectifier," by R. P. Jackson, The Electric Journal, May, 1909, p. 264.

e.m.f. induced in the secondary winding of the transformer. The first curve was taken when the rectifier was running at full load and the second when at one-fourth load. By transferring one terminal of the oscillograph voltmeter from P_1 to K, the other terminal remaining connected to the same point, M, oscillograms, such as curves *3* and *4*, Fig. 3, will be obtained, showing the result of the valve action of the rectifier bulb. In this case rectification of the entire e.m.f. wave is indicated by the fact that the electrical pressure across M and K is uni-directional, though very fluctuating. By shifting the same terminal of the oscillograph voltmeter still further to L, still keeping the other terminal connected at M, the result of

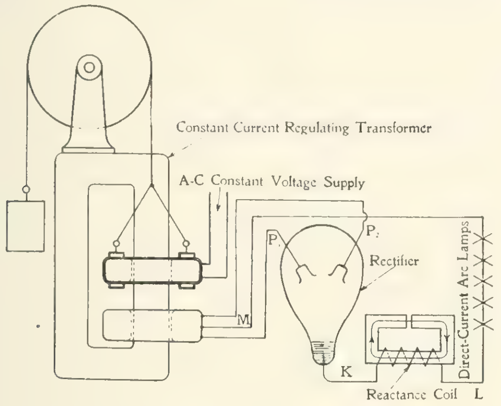
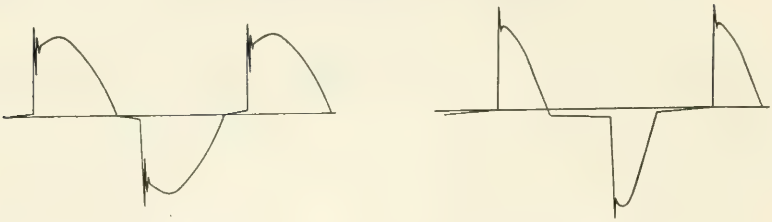


FIG. 2—DIAGRAMMATIC VIEW OF SELF-SUSTAINING CONSTANT-CURRENT RECTIFIER SYSTEM SUPPLYING CURRENT TO DIRECT-CURRENT SERIES ARC LAMPS FROM AN ALTERNATING-CURRENT, CONSTANT VOLTAGE SOURCE OF POWER

the smoothing action of the reactance coil on the load voltage curve is shown by the oscillograph. Nearly a straight line is obtained, as illustrated by curves *5* and *6*, Fig. 3. To find out how this is performed by the reactance coil, it is only necessary to connect the terminals of the oscillograph across the reactance coil. Curves such as *7* and *8* will be obtained, showing that the hump of each wave of the alternating-current supply e.m.f. is cut off, stored and then utilized for filling the slump in voltage which follows a moment later, as a result of the fact that the voltage delivered by the bulb does not reach the full value required by the load. This is what the reactance coil does once every half cycle to smooth down the "ragged"

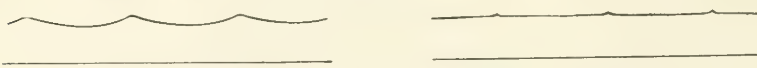


Curve 1—Full Load. Curve 2—One-Quarter Load.

E. M. F. Induced in the Secondary Winding of the Transformer.

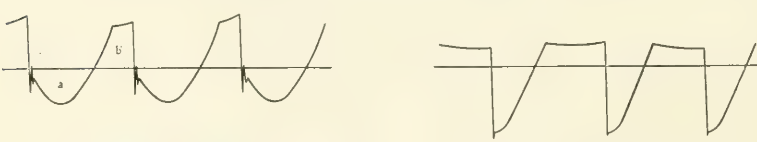
Curve 3—Full Load. Curve 4—One-Quarter Load.

E. M. F. Across the Middle Point of Transformer Winding and the Cathode Terminal of the Bulb.



Curve 5—Full Load. Curve 6—One-Quarter Load.

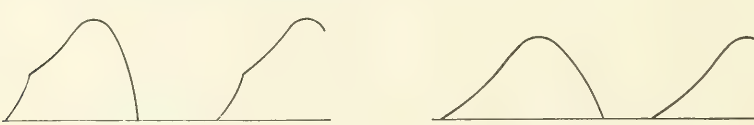
Voltage Across the Load.



Curve 7—Full Load. Curve 8—One-Quarter Load.

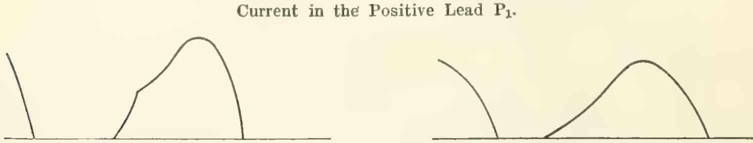
a.—Voltage choked by the reactance coil.
b.—Voltage supplied by the reactance coil.

E. M. F. Across the Reactance Coil.



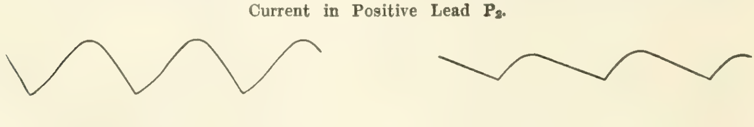
Curve 9—Full Load. Curve 10—One-Quarter Load.

Current in the Positive Lead P_1.



Curve 11—Full Load. Curve 12—One-Quarter Load.

Current in Positive Lead P_2.



Curve 13—Full Load. Curve 14—One-Quarter Load.

Rectified Current.

FIG. 3—OSCILLOGRAMS FROM VARIOUS PARTS OF THE RECTIFIER CIRCUIT

e.m.f. supplied by the rectifier bulb, making it suitable to the requirements of the load; and the oscillograph tells the whole story in a simple and concise way.

Oscillograph curves *9* and *10*, Fig. 3, show the wave-form of the current in the positive lead, P_1, Fig. *2*, of the rectifier bulb, and curves *11* and *12* represent the current in the other positive lead, P_2. Their intermittent and uni-directional character is plainly shown. The result of the uniting of the current in the positive leads, which is the rectified current, is shown by curves *13* and *14*.

STUDY OF THE OSCILLOGRAMS

It will be noticed that each e.m.f. wave of the supply voltage curves *1*, *2*, *3* and *4*, Fig. 3, is cut off somewhat at its start. This takes place when the current is transferred from one positive terminal to the other in the process of rectification. During the period

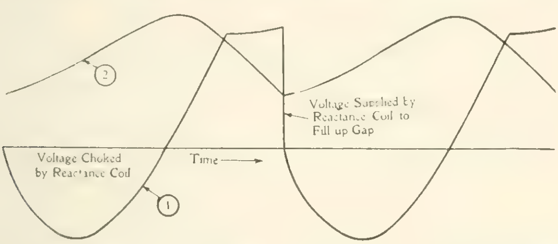


FIG. 4—E.M.F. AND CURRENT CURVES OF REACTANCE COIL

of transferance of current, it flows in both leads, uniting in the bulb. This amounts to momentarily short-circuiting the terminals of the transformer, and during this period of short-circuit no voltage is induced in the secondary winding except that which is used to transfer current from one lead to the other. The voltage required to maintain the load voltage is supplied from the reactance coil, as already explained. The duration of the short-circuit depends upon: the e.m.f. wave-form generated in the armature of the alternator supplying the power; the inductance of the supply circuit, including that of generator; the inductance which exists between the primary and the secondary windings of the transformer, and also the inductance between the halves of the secondary winding. Since a constant-current regulating transformer has a large inductance between its primary and secondary windings (it performs its function of regulating current by adjusting the amount of this inductance), the arc lighting rectifier outfit has, necessarily, a long period

of short-circuit amounting to from 40 to 60 electrical degrees.

If from these oscillograms another curve, Fig. 5, of e.m.f. and current in the reactance coil, Fig. 4, be plotted, the ordinates of which are the products of the ordinates of the e.m.f. curve of the reactance coil and of the current in it, an energy curve of the reactance coil will be obtained which will show more clearly the function of the reactance coil. It is seen to first absorb energy and then discharge it as required to overcome the pulsating character of the single-phase source and give steady flow of power. Moreover, by measuring the area representing the absorption and discharge of energy by the reactance coil the difference will give the loss of energy in the coil.

In a previous article* it was pointed out that different readings were obtained from various types of ammeters, placed in the direct-current circuit of a rectifier system. Probably some have noticed the same thing when attempting to check ammeters of different types by connecting in circuit with a rectifier outfit. For instance, a permanent magnet type of ammeter, such as the Weston direct-current ammeter, will indicate four amperes when connected in the circuit of a four-ampere arc-lighting rectifier outfit; but a dynamometer type of ammeter, such as a Siemens current dynamometer or Kelvin balance ammeter, will indicate a higher value, probably 4.1 amperes, while another type of ammeter constructed on the induction principle, such as Westinghouse types *F, G, I* or *P* ammeters, will give still different readings, perhaps 0.9 ampere. Of course the relative values of their indications depend upon the amount of the fluctuation of the rectified current. But when the current is examined with the oscillograph not only does this confusion disappear, but it is found that the readings of all types of ammeters are correct, though widely different, according to the nature of their indications.

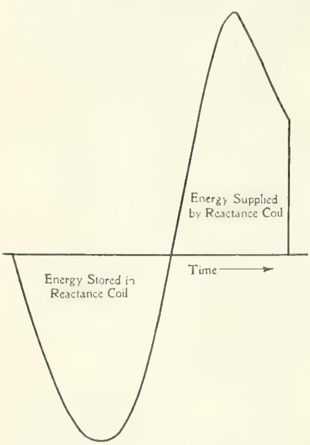


FIG. 5—ENERGY CURRENT OF REACTANCE COIL

The fluctuating current obtained from a rectifier can be considered as composed of alternating current and direct current, the

*See THE ELECTRIC JOURNAL for July, 1908, p. 401.

one superimposed upon the other; the less the fluctuation the less the amount of alternating-current in the resultant wave. As the permanent magnet type of an ammeter does not respond to alternating-current it will indicate the direct-current component only, while the dynamometer type, as it responds to both alternating-current and direct-current, will indicate the effective value of the resultant of the two components, and the induction type will indicate the alternating-current component only. Therefore, the example cited above shows that the fluctuating current is composed of four amperes of direct-current and 0.9 amperes of alternating-current.

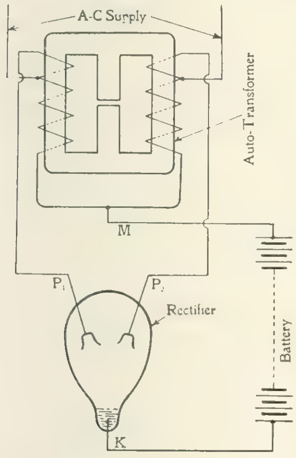


FIG. 6—DIAGRAMMATIC VIEW OF SELF-SUSTAINING RECTIFIER SYSTEM CHARGING STORAGE BATTERY

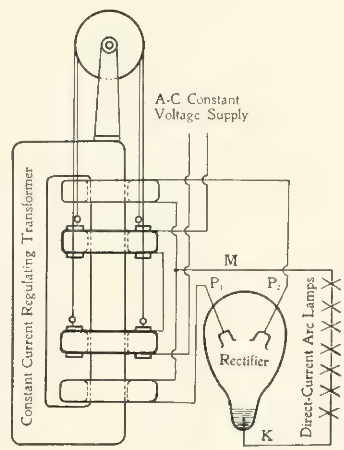


FIG. 7—DIAGRAMMATIC VIEW OF SELF-SUSTAINING CONSTANT-CURRENT RECTIFIER SYSTEM SUPPLYING CURRENT TO DIRECT-CURRENT SERIES ARC LAMPS.

It may be noted, in addition, that another type of ammeter, in which the magnitude of the current is indicated by the amount of its magnetic pull upon a small piece of iron which is highly saturated magnetically, will show higher values than the permanent magnet type, but lower than the dynamometer type when put in a rectifier circuit.*

LATER IMPROVEMENT OF RECTIFIER SYSTEM

The rectifier system discussed in the previous paragraphs is of the form of the original development and this form has been

*See also "The Action of Direct-Current Meters on Rectified Circuits," by Mr. Paul MacGahan, in the JOURNAL for November, 1909, p. 700.

considered in order to present a clear view of the processes of rectification by the rectifier bulb and the "cut and fill" action of the reactance coil. The original form was later improved by Mr. Frank Conrad by incorporating the action of the reactance coil in the transformer, producing what is called the "self-sustaining" transformer. The essential features of the latter arrangement for a storage battery charging outfit and an arc-lighting outfit, respectively, are shown diagrammatically in Figs. 6 and 7. The principal difference between the old system and the new is that the windings are each divided into two parts, between which a magnetic field is built up. This auxiliary field plays the part of the reactance coil while the transformer is performing its primary duty.

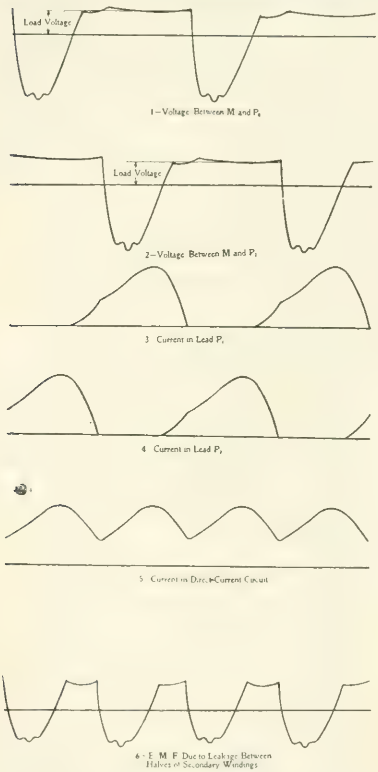


FIG. 8—OSCILLOGRAMS FROM VARIOUS PARTS OF THE CIRCUIT OF THE LATER FORM OF SELF-SUSTAINING MERCURY RECTIFIER OUTFIT

In this form of self-sustaining transformer the voltage between its middle tap *M*, Fig. 6, and one of the positive leads *P*, is the load voltage while the lead is active, as shown by curve *1*, Fig. 8. The reason for this is that the cut and fill action of the reactance coil, explained in connection with the older form of apparatus has already been performed by the transformer itself. The manner in which it is accomplished can be shown with the aid of the oscillograph by connecting to it an exploring coil so placed as to inclose the fluctuating magnetic flux between the halves of the secondary windings. Curve *6*, Fig. 8, is the oscillogram thus taken. It will be seen to be similar to curve *7*, Fig. 3, for the reactance coil. The remaining oscillograms of Fig. 8 showing the e.m.f. and current wave-forms correspond, respectively, to those of Fig. 3 taken from the older form of apparatus.

THE NEW QUARTERS OF THE ELECTRIC CLUB

A. W. LOMIS,
President

THE readers of the JOURNAL will doubtless be interested in the new quarters which are soon to be occupied by The Electric Club, the organization under whose auspices the JOURNAL is issued. The Electric Club was organized in the spring of 1903, its members consisting principally of the engineers and the engineering apprentices of the Westinghouse Electric & Manufacturing Company. A large proportion of the activities of the Club have been carried on by the engineering apprentices. These apprentices are graduates of various colleges and technical schools, who are taking a two-year post-graduate course in the electric works. While the majority of the members are from the Electric Company, the membership includes quite a number of men from the other Westinghouse Companies.

The Club is most widely known through THE ELECTRIC JOURNAL, which was instituted at the beginning of 1904 and is now in its seventh year.

Since its organization the Club has occupied the quarters on Penn Avenue, in Wilkinsburg, a residence suburb of Pittsburgh. These were described in the first issue of the JOURNAL by Mr. H. W. Peck, then president of the Club. In order that the growing activities of the Club may be better accommodated, arrangements have recently been made by which larger quarters have been secured in a location more central to all members.

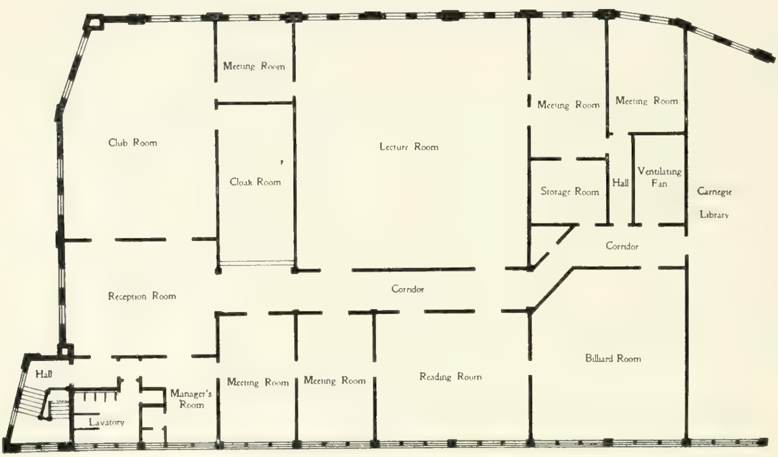
The general purpose and scope of the Club were well presented in an article by Mr. F. D. Newbury, then president, in the JOURNAL for September, 1906. The work of the Club has since continued along the lines indicated by Mr. Newbury, and at the present time, the varied kinds of Club work are, in general, conducted by committees of Club members in which the younger men largely participate. There is a weekly lecture course, a part of the lectures being given by local men, and a part by prominent men from a distance. There are also a number of bi-weekly sections dealing with technical and commercial subjects, such as:—

A Power Engineering Section.
An Industrial Application Section.
A Railway Section.
A Project Section.
A Sales Section.
An Esperanto Section.

These sections are usually conducted by the younger men, who call to their assistance from time to time those who are older and more experienced in the particular subject under consideration.

There are also excursion sections which afford facilities for visits to coal mines, the steel and wire mills, the glass companies, the power plants, and other industries and notable features in and about Pittsburg.

The new quarters include nearly all of the Royal Building. This building is nearly opposite the Wilkinsburg station of the Penn-



PLAN OF UPPER FLOOR OF NEW QUARTERS

sylvania Railroad and is convenient to all the street car lines in Wilkinsburg. The general club rooms are on the upper floor, which has been specially laid out for the Club purposes in accordance with the accompanying plan. This arrangement provides an auditorium for general meetings, and also a number of smaller rooms for committee and section meetings. There is a large general club room and other rooms for reading and amusement. On the same floor and adjoining the Club rooms is the Wilkinsburg branch of the Carnegie Library.

A gymnasium 65 feet wide by 140 feet long on the lower floor is being equipped with up-to-date apparatus, with shower baths and locker rooms adjoining. An experienced physical director has been

secured and the formal opening of the gymnasium for regular class work under systematic direction will be announced soon. In the meanwhile the gymnasium is being used for the Club basket-ball games. Special provision is being made for hand-ball, basket-ball and indoor-baseball and other games which will be of interest to the members, and it is planned to have regular games with various teams under the direction of the athletic committee of the Club. The Club has had for a number of years a tennis field which is largely used during the summer.

VIEW OF GYMNASIUM FLOOR OF NEW QUARTERS
Taken before the building was remodeled.

There are committees having various social functions in charge. The athletic activities have been somewhat limited in the past owing to the lack of suitable facilities but they will undoubtedly become one of the strong features of the Club after the new quarters are occupied.

STATIC STRAINS IN HIGH-TENSION CIRCUITS*

PERCY H. THOMAS

The JOURNAL has arranged to print a series of articles on the general subject of continuity of service in transmission systems dealing particularly with line stresses and static troubles and the protection from the same. Some of these, on account of their perennial interest, will be reprinted from papers read before the A. I. E. E., others will be original. The following paper is reprinted in revised form on account of its accurate and simple method of explaining the stresses to which higher voltage apparatus is subject. Other articles will be by Mr. P. M. Lincoln, Mr. J. S. Peck, Mr. S. M. Kintner, and Mr. R. P. Jackson.

IT is the purpose of the present paper to discuss the so-called "static effects" in high-tension circuits, especial attention being given to the disturbances produced by lightning, switching, grounding and the like. Some discussions of particular phases of the princples involved have been published from time to time, but so far as has come to the attention of the author, no comprehensive treatment of the subject of a non-mathematical character has yet appeared. On this account a general view of the question without mathematical complication will probably prove of interest to superintendents and station managers as well as to electrical engineers. Necessarily much of the matter in the paper will not be new, but it will be found that the old principles when applied to commercial circuits yield quite novel and important results.

It is scarcely necessary to state that static strains, though not perhaps particularly destructive of themselves, may indirectly cause the loss or temporary disabling of expensive and important apparatus. One of the principal aims, if not the chief aim of the superintendent of a modern electric transmission system, for the accomplishment of which he will make great sacrifices, is to keep his service continuous. Static disturbances in such systems, when not properly controlled, are a constant menace to the continuity of the service. The prominence of static effects is one of the chief distinguishing characteristics of high-tension operation. The importance of "static" is not emphasized solely on theoretical grounds.

*Extract from a paper read at the 160th meeting of the American Institute of Electrical Engineers, at New York, 1902. Revised by the author, February, 1910.

Plants in actual operation have suffered both damage to apparatus and loss of prestige on account of insufficient static protection.

For the present discussion, "static" will be taken to include those changes of potential and waves of current of an abrupt nature which result from the transfer of the electrostatic charges of a system from point to point. Such actions are not directly produced by the generator, although practically all phenomena in a circuit, except those due to lightning are produced at least indirectly by the generator.

Every electric circuit may be viewed in two ways. It may be regarded (as in dealing with the transmission of power) as a closed circuit containing resistance and inductance, and carrying a certain current produced by a certain e.m.f., or it may be regarded (as in dealing with static) as a large insulated "conductor"' (as the term is used in treatises on static electricity) of peculiar form. That is, the circuit performs a double function. It transfers useful energy and at the same time acts as an electric condenser. The first aspect, being the one of greatest practical importance, is the one almost universally considered. However, even in this case, with long, high-tension lines, it has been found necessary to give some attention to the electrostatic capacity of the circuit taken as an insulated "conductor." The second aspect of the circuit is the one to be here considered, and though of less importance than the first, it still deserves careful consideration on account of the serious difficulties static may cause in commercial work. As a matter of fact, since the electric circuit when operating is at the same time both a closed circuit carrying current and a charged, insulated "conductor," the actual resultant condition of the system is a combination of these two states.

There are some points of difference, however, between the commercial electric circuit and the insulated "conductors" commonly used in the laboratory demonstrations of static electricity. In the first place, the commercial circuit is very much the larger and is extended over greater distances, so that a sensible time is required for an electric impulse to pass from one end to the other. Consequently, the points on the same conductor may be momentarily at very different potentials. In the second place, the amount of energy stored in the electrostatic capacity of the commercial circuit is very much larger than in the "conductors" of laboratory ex-

periments. It should be noted that these points of difference are both differences of degree, not of kind.

It will be well at the outset to summarize briefly the most characteristic of the laws of static.

FIRST LAW OF STATIC

A static discharge (which is merely a very sudden rush of electricity) encountering a choke-coil in its path, experiences momentarily great opposition, i. e., the electricity is temporarily held back by the inductance of the coil, so that if the rush of electricity be of large volume and sufficiently sudden, a very great e.m.f. (neglecting losses of energy) will be exerted on the choke coil. This high e.m.f. is but momentary, however, as the choke coil after the first instant allows the electricity to pass at an accelerating rate which soon relieves the pressure. The high momentary pressure at the front of the choke coil causes a tendency for the charge to seek other paths. Such a phenomenon would be called "side flash" and is one of the considerations which led to the use of choke coils with lightning arresters. Lightning arrester choke coils are so placed that any static disturbance on the line must pass the choke coil to reach the apparatus which is being protected, and the arresters are placed on the line side of the choke coils, where the tendency to side flash is strongest.

As there is a tendency to side flash toward other objects, there must evidently also be a tendency to short-circuit the choke coil itself. Such short-circuits are by no means unusual when coils not designed to withstand them are exposed to static discharges.

SECOND LAW OF STATIC

All conducting bodies have electrostatic capacity, or in other words are to a greater or less degree condensers. Whenever a conductor is at a potential different from a neighboring conductor, a charge of electricity appears in its surface principally on the side toward the other body. The amount of this charge equals the product of the electrostatic capacity and the potential between the bodies. At the same time an exactly equal charge appears on the second body. A conductor may have capacity to two or more adjacent conductors at the same time; in this case its resultant charge is the sum of the separate charges.

The fact that a certain quantity of electricity, great or small, is required to charge any conductor to any definite potential is very

important in its bearing on long-distant lines. Suppose, for instance, that a piece of apparatus at one end of a transmission line is to be raised to a certain potential by a sudden application of voltage at the other end. A sensible time will elapse before the necessary charge for the apparatus can reach the end of the long line. Consequently, the potential of the apparatus will not rise at the same instant as the applied e.m.f., but will remain unchanged until the charge actually reaches it.

The large current required to charge the line wires of an extensive high-tension system is well known. All switches, transformers, instruments and other apparatus actually connected to the high-tension circuit also require charge, though of course much less.

The line wires have electrostatic capacity both to the earth and to one another. The several charges corresponding to these different capacities, though superposed on the wire, act independently of one another and must be so studied. Similarly with apparatus connected to the lines, not only will there be electrostatic capacity in the high-tension parts to ground and low-tension parts, but also between different parts of the high-tension windings themselves.

THIRD LAW OF STATIC

When a current is flowing through a circuit containing inductance, energy is stored in its magnetic field. The amount of this energy equals one-half the product of the inductance and the square of the current. This energy was obtained from the circuit when the current was started and, when the e.m.f. producing the current is removed, must be discharged back into the circuit before the current can stop. If the circuit be opened suddenly, a very high potential will be developed to keep the current flowing until this energy is fully discharged. Such is the case of the well-known rise of potential which results from suddenly opening the field circuit of a large generator. The direction of this "extra" e.m.f. is such as to continue the current flow.

Energy in a magnetic field is just as truly stored energy as that in the moving bullet, the stretched spring, or the raised weight. It may be adapted to useful purposes. For example, the energy stored in the magnetism in the core of an induction coil by the primary current is discharged into the secondary to produce a high-tension spark.

An idea of the amount of this energy in actual cases may be obtained from the following: One ampere flowing through a coil

with an inductance of 1 henry (equivalent to 377 ohms at 60 cycles) stores ½ volt-ampere-sec=½ watt-second,=½ joule=0.367 foot-pounds.

The very sudden rushes of static electricity are no exception to this law; they produce magnetism and store energy which must be discharged into the circuit again before the currents can cease. This principle will be found to lead to important results.

Also, when a condenser is charged, energy is stored. This energy will be restored to the circuit again when the condenser is discharged. The amount of this energy is one-half the product of its electrostatic capacity and the square of the voltage.

A condenser of one miscrofarad capacity charged to 1 000 volts potential stores ½ watt-sec.=½ joule=0.367 foot-pounds.*

The energy of an electric current may thus be stored in two ways: Either in a magnetic field produced by a current, or by the storing of the electricity itself. In its former state the energy may be regarded as kinetic and in the latter as potential.

FOURTH LAW OF STATIC

When a condenser discharges suddenly through an inductive circuit containing comparatively little resistance, the current in the discharge path increases steadily until the condenser is completely discharged. At this time the current, in virtue of the magnetic field which it produces, stores nearly the full amount of the energy originally in the condenser, for there is little waste, as the resistance is assumed to be small.

But this current cannot become zero until all its energy is discharged into the circuit, which in this case means into the condenser; therefore, the condenser is charged to its original voltage

*The transmission lines of a system with lines 150 miles long have a capacity of about 3 microfarads. Operating at 40 000 volts, this will have $1/2\ (3 \times 10^{-6}) \times (40\,000 \times \sqrt{2})^2 = 4\,800$ watt-secs = 4 800 joules, = 3 500 foot-pounds of energy stored in its electrostatic capacity when fully charged. The charging current is 45 amperes at 40 000 volts, 60 cycles. Therefore, the rate of supply of energy to the line from the generator and absorption from the line by the generator is $45 \times 40\,000 \times 2 \times \frac{1}{\pi} = 1\,150\,000$ watts, = 1 150 000 joules per sec., = 843 000 foot-pounds per sec. The generator supplies current continuously to the line for 1/4 cycle and then receives it back again for the next 1/4 cycle. Therefore, the energy delivered or received in a half alternation is the energy stored in the capacity of the line $= \frac{45 \times 40\,000 \times 2}{\pi \times 60 \times 4} =$ 4 800 watt-secs. = 4 800 joules = 3 500 foot-pounds, as before.

again, but this time in the opposite direction. At the instant all the energy is thus restored to the condenser (with reversed direction) the current is zero. But the condenser cannot remain charged with the discharge path closed, and will discharge again, repeating the same phenomena; that is, the charge oscillates backward and forward through the discharge circuit. If the resistance is not zero a little energy is lost every time discharge occurs, so that each time the condenser is charged to a lower potential than the preceding time until the whole of the energy is finally transformed into heat. If now a condenser be charged through inductance, energy will be steadily stored in the magnetic field produced by the charging current (just as in the case of discharge) until the condenser has reached full potential. All this energy must be discharged into the condenser before the charging current can cease; that is, if there are no sensible resistance losses, the condenser will be charged momentarily to double potential. The condenser will then oscillate between double potential and zero until it finally settles down at the potential of the circuit from which it is charged, which occurs only as the oscillations are damped by the resistance of the circuit or by other losses. These phenomena may be made clearer by mechanical analogy.

The first case of the discharging condenser is similar to that of a pendulum which has been drawn aside and released; it oscillates about its final position of rest until its energy is all expended in friction. The second case may be compared to a weight supported by a spring. If the weight be dropped it will descend beyond the point at which it is finally to come to rest, stretching the spring to twice its final extension. The weight will then be drawn up again above the point of equilibrium, oscillating backward and forward until its energy is dissipated by friction. The inertia of the weight corresponds to the inductance of the charging circuit, and the elasticity of the spring corresponds to the capacity of the condenser.

ELECTRIC CIRCUIT AS AN INSULATED CONDUCTOR

It has been stated that an electric circuit may be considered as an insulated conductor of a peculiar form. It is rather an aggregation of conductors of various forms. In general a high-tension circuit consists of the following parts:

(*a*) The high-tension transformer windings. These are in the form of coils, and are therefore from the static point of view,

choke coils. On account of the very large number of turns their choking power is very great (choking power in general being proportional to the square of the number of turns). The high-tension windings have electrostatic capacity also, as they lie close to the low-tension windings and to the core, that is, the high-tension winding will have static charges on the surface opposite the low-tension winding and opposite the core. There is as well, capacity between turns and between coils of the high-tension windings. The electrostatic capacity of these transformer coils is of a rather complicated nature, for it is distributed along at different points on the winding, and is not concentrated at one point as in an ordinary condenser. Therefore, the charge for the different portions of the windings must pass through different lengths of wire and different amounts of inductance and resistance. The same is true of both raising and lowering transformers.

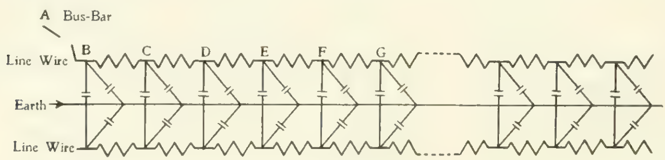


FIG. 1—DIAGRAM ILLUSTRATING INDUCTANCE AND CAPACITY OF A LONG SINGLE-PHASE TRANSMISSION LINE

(*b*) The transmission lines. The wires have electrostatic capacity with one another and with the earth, so there are two or more charges superposed on each wire—each of which may act independently of the others. This capacity, though comparatively small for short lengths of wire, is, as a whole, large, on account of the great length of the lines. These wires have inductance also, like the capacity, small for short lengths, but quite considerable when the line is taken as a whole.

On the line wires, as in the high-tension transformer windings, the electrostatic capacity and inductance are distributed, so that when the voltage is applied to the line, different points receive charging current at different instants of time, since the charge for various points must flow through different lengths of line. In fact, the transmission wires may be considered as a succession of choke coils and condensers in series, each very small, but very great in number, as shown in Fig. 1.

In addition to the electrostatic capacity of the line wires, there

is a certain amount of capacity on each insulator. The amount is very small, and may be considered part of the line capacity.

(*c*) Switches, instruments, lightning arresters, station wiring, and similar auxiliary apparatus. These all have a certain amount of electrostatic capacity to surrounding objects, but not usually as much as the high-tension windings of transformers. This part of the system has also comparatively little inductance and needs no further discussion here.

In addition to electrostatic capacity and inductance, all parts of the high-tension system have more or less ohmic resistance. The effect of this resistance is to retard the current (static or normal) in whatever direction it flows, and to change part of the electric energy into heat.

A certain amount of current leaks from the line at insulators and at all points where insulating material touches the circuit, since no insulation is perfect. Even the air conducts away some charge when the voltage is extremely high. Taken together, the result of these leakages is small under normal conditions, and may be neglected in this discussion.

Every point of a high-tension circuit at any instant has a perfectly definite potential which is in general different from the potential of other parts of the circuit and of adjacent objects. Consequently each point has at each instant a definite static charge, often different from that of other points. As (with alternating currents) the potential of each point is varying from instant to instant, these charges are continually changing and the changing charges cause a current in the circuit properly called charging current. Neither this charging current nor the static charges have any connection with the useful current except as the latter may influence the static potential of some point of the circuit. The total current in the circuit at any instant is the sum of the work current and charging current, if they are in the same direction, or their difference if they are in opposite directions.

When the potentials of all points of a circuit are determined directly by the electromotive force of the generator, i. e., during normal operation, all changes of potential are slow (compared with static changes of voltage) and allow sufficient time for the necessary changes in the static charges at various points to be accomplished without serious opposition from the inductance of the circuit. Such changes of potential and charges as these, however, are not the subject of this paper. Its principal object is the discussion

of changes of potential of a more abrupt nature which are not directly produced by the e.m.f. of the generator; the latter may cause violent and sudden alterations of the static charges and dangerous local potential strains. However, before taking up the more complicated case of the abrupt changes, it will be best to consider a little more fully the distribution of potential and charge in some of the simpler cases of normal running, viz:

A Symmetrical Single-Phase Transmission Line, Open-Circuited at the End, and Charged by a Direct-Current Generator—In this case both lines have the same electrostatic capacity to the earth. There is also capacity between the line wires. On the positive line is a positive charge composed of two parts, one due to its capacity to earth and the other to its capacity to the other wire; similarly on the negative wire is an equal negative charge composed of two parts. These charges remain constant as long as the e.m.f. of the generator is constant.

If, however, the generator be an alternator, the charges change from positive to negative with the voltage, remaining equal on the two wires at all times. This interchange of charges requires a flow of current from line to line through the generator.

When the same line is loaded at the farther end no material change is produced in the line charges. Since different parts of the high-tension winding of the motor or transformer or other apparatus constituting the load, are at potentials varying all the way from one-half line voltage positive to one-half line voltage negative, the charges on these points will vary in a simliar manner. These charges are supplied from the generator through the line. The charges for the inner parts of the winding of the load apparatus must flow through the outer parts of the windings as well as through the line.

Same Line with One Leg Grounded—Since direct current is practically never used in high-tension work it will be omitted from further discussion here. The case of a grounded line is of importance not as a practical operating condition, but on account of the harmful results which may follow accidental grounds. The potential of one line wire becomes the same as that of the earth, while that of the other is full line voltage, or double its value when the circuit is ungrounded. The potential between the wires being maintained by the generator, remains unchanged. Of the two component parts constituting the charge on the ungrounded wire, the part due to electrostatic capacity between the wires is undisturbed by the grounding, since the voltage between wires is unchanged—the

part of charge due to capacity to earth becomes zero, since the potential to the earth is zero. The charge which appears on the earth opposite the ungrounded wire and which is equal in amount to the part of that line's charge that is due to capacity with the earth, being produced by the generator, must flow to earth at the point where the circuit is grounded. On a large system the electrostatic capacity of the lines would be sufficient to make this current quite large. In such a case the current may burn off the line wire at the grounded point if the contact with the earth is imperfect. This fact has a very direct bearing on the question as to whether it is possible to operate a large high-tension system with one wire accidentally grounded.

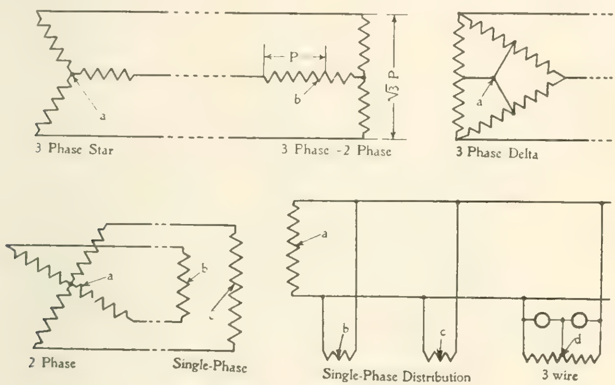


FIG. 2—NEUTRAL POINTS

System with Neutral Point Grounded—In a symmetrically arranged ungrounded system, either single-phase or polyphase, a neutral point may be defined as any point which is at the earth's potential. There may be more than one neutral point in a circuit as shown in Fig. 2, where *a, b, c, d* are neutral points.

Since the neutral point is at the earth's potential, grounding this point makes no difference in the potential or charge of any point of the circuit, and no current flows over the grounding wire. If the circuit becomes unbalanced, for example, by a high resistance ground on one wire, there is a tendency for the neutral point to take a potential different from that of the earth, and a current will then flow over the grounding wire, which will be sufficient to keep the neutral point at earth's potential. If there be a dead ground on one wire the earth connection at the neutral point completes a short-circuit. If the neutral point is not grounded when the sys-

tem becomes unbalanced, one or more lines will take a potential higher above the earth than in the balanced condition, and the other line or lines a potential lower than before. Therefore, comparing the two methods of operation, with the neutral grounded, if a "dead" ground is made on any line wire, a short-circuit is produced through the ground connection at the neutral point; with the neutral ungrounded a ground on a line wire means approximately twice the previous potential between the line and ground on one or more wires, though no short-circuit is produced. The advantage of a grounded neutral is the preventing of increased potential over the earth in case of an accidental ground; its disadvantage is the fact that one such accidental ground, instead of two, causes a short-circuit.

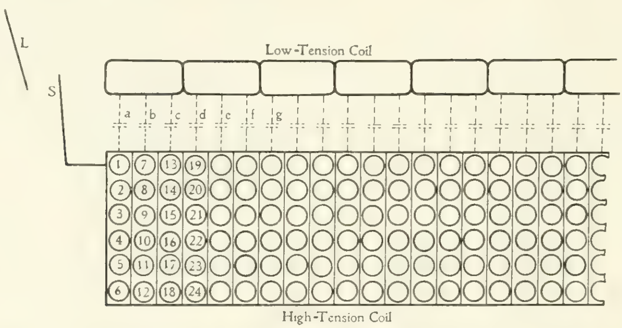


FIG. 3—DIAGRAM ILLUSTRATING ELECTROSTATIC CAPACITY OF A HIGH-TENSION TRANSFORMER COIL

We may now consider some of the abrupt changes of potential not directly produced by the generator.

CHARGING A "DEAD" TRANSFORMER

Fig. 3 represents the portion of a high-tension transformer coil connected to the line terminal. The circles indicate wires. The coil may have one or more turns per layer. The numbers on the circles indicate the order in which the current passes through the turns of the winding. The low tension winding lies adjacent to the high-tension and the small condensers *a, b, c, d,* etc., shown dotted, indicate the electrostatic capacity of the corresponding wires to the adjacent low-tension coils.

Before either terminal of the transformer is connected to the line, all parts of the high-tension winding are at earth's potential. As the first line switch is being closed at *s,* there is no change in the

potential of the transformer winding until a spark passes between the switch jaws. Then instantly the potential of the transformer terminal is raised to the potential of this line wire. The rest of the high-tension transformer winding also takes the potential of this line wire as soon as (but not sooner than) the necessary charge can reach *b-c-d-e,* etc. Now, the charges for *b-c-d-e,* etc., must flow through a considerable amount of inductance, which will require a length of time which is very short but still sensible. It is clear that during this short but definite period, after the terminal has reached its full potential and before there has been sufficient time for the charge to reach the inner layers, for example, *f* and *g,* etc., a difference of potential exists between the outer and inner layers of the winding, which is equal to the full e.m.f. of the line wire above the earth. If the insulation of the winding is too weak, or the line potential is sufficiently high, this momentary difference of potential will cause a spark to pass over the surface of the coil, or through its insulation. This spark contains a very small amount of electricity, for as soon as the wires, *f, g,* etc., are charged up to line potential, the voltage between the inner and outer layers vanishes. The only result is the almost harmless passage of a nearly invisible spark.

Very soon after the closing of the first line switch the whole transformer winding will have assumed the potential of the first line wire, that is, just before the closing of the second line switch, the second transformer terminal is at the potential of the first line. As the second switch is closed, a spark passes, and the potential of the second terminal of the transformer which has up to this instant been at the potential of the first line, is suddenly changed to that of the second line—a very abrupt change. Then, as before, during the period required for the necessary charge to penetrate to the inner turns, a very high potential difference is impressed on the outer portion of the coil. The momentary strain on the insulation of the coil is greater when the second switch is closed than the first, for the first transformer terminal experienced an abrupt change only from earth's potential to line potential, while the second was changed from the potential of one line to that of the other line, which is nearly double the potential from the ground.

There is another very important difference between the effects of closing the first and second switches in connecting a "dead" transformer to a live line. In the case of closing the first, as already stated, if the momentary strain breaks down the insulation, only sufficient

current flows through this break to charge up the inner layers of the transformer coil. This is a very small quantity and can do comparatively little injury to the coil, especially if it be oil-insulated. In the second case, the amount of current passing in the static spark is not materially greater than in the first case. But when the insulation between turns is momentarily broken down by this small spark, there flows through the break a certain amount of current due to the e.m.f. impressed by the generator on each turn of the coil. Although the static spark of itself would be but momentary, yet the current supported by this impressed or "normal" e.m.f. of the circuit may be able to hold the arc and continue indefinitely, destroying the whole coil if not interrupted. I say, "*may* be able to hold an arc," for such an arc may or may not be held, according to the circumstances of the case. If the static spark passes when the normal e.m.f. is nearly zero, or if the transformer be not able to supply much current in short-circuited turns, etc., then the chance that a permanent arc will be established is small. Sparks or flashes have actually been observed in the windings of high-tension transformers at the time of lightning discharges, showing actual temporary holding of an arc.

The factors which determine the minimum number of layers upon which excessive momentary potential will be impressed are, chiefly, the inductance and electrostatic capacity of the transformer coils and the abruptness of the change of potential of the terminal on the closing of the switch. The former determines the rate at which the charge can penetrate the coil, and the latter determines the time during which charging current may be passing into the coil before the full potential is reached on the terminal. The more abrupt the spark and the greater the capacity and inductance of the coils, the fewer the number of layers which wlll become charged before the full terminal potential is reached, and the more severe will be the strain on insulation.

When switching is done on a high-tension generator or a motor or any apparatus containing coils, a strain is brought in the windings near the terminals in exactly the same way as with transformer coils. There is also, usually, this same tendency for normal voltage to cause an arc to follow any momentary break in the insulation.

It is evident that the danger from this sort of switching is greater and greater for higher and higher voltages; it is of little importance on low voltages. Actually, injury of a serious nature

to apparatus from this source is very much less than would be at first expected for several reasons:

(*a*) Insulating materials will stand much higher voltages of a static nature than of a continuous nature, such as those derived from generators.

(*b*) The passing of a static spark alone is usually by no means a serious matter and many circumstances may prevent a destructive arc from following the spark.

(*c*) It is only occasionally that the combination of circumstances arises which gives the severest conditions.

It has been assumed thus far that the potential of the line wires is unaffected by the switching operations. If, however, the connecting of the transformer to the line momentarily lowers the line potential at the switch, as will often occur, the abruptness of the static strain, and therefore its severity, will be reduced.

This discussion which has been applied to switching on a transformer, is applicable when any coil is subjected to an abrupt change of potential in any part. For example, when a dead transmission line is connected to a live transformer the potential of the transformer terminals will usually be suddenly lowered very considerably for the moment, on account of the great excess of electrostatic capacity in the line over the transformer coil. In this case the potential of the line which must be charged directly by the generator (and not from charge previously stored in the electrostatic capacity of other lines) will rise very much more slowly, since current must pass through considerable inductance in generator and transformers. Sudden short-circuits, grounds, discharges of lightning arresters and similar disturbances all produce static strains more or less severe according to the circumstances.

CHARGING A SHORT TRANSMISSION LINE

In considering the charging of a short transmisson line, the line may be considered to be a condenser. Assuming that it is being charged from bus-bars rigidly maintained at constant potential, there will always be a certain amount of inductance in the path through which the charging current must pass to reach the line, so that we have the case of the charging of a condenser through inductance with more or less resistance in the circuit. Therefore, when the line is connected, it rises to double potential (neglecting losses) and immediately starts to oscillate between this point and zero

until the oscillation gradually dies out and leaves the line at normal potential.* This means that at all points the insulation of the line will receive a strain of double potential. If, on the other hand, the bus-bar from which the line is charged has not the capacity to deliver almost instantly the amount of electricity necessary to charge the line, the first effect of closing the switch will be not to raise the potential of the line to its full amount, but to make both line and bus-bar take an intermediate potential so that the line comes up to normal potential by steps. Under these circumstances, the maximum of the oscillation is materially reduced, and the line is not subjected to a double potential. In the extreme case in which the bus-bar has a comparatively small capacity to deliver current, the first effect of connecting the line is to bring the potential down to zero. In this case, if the line be charged from transformers, the outer portions of the winding are subjected to severe strains, as already explained. For a bus-bar to be able to supply charging current to a "dead" line so quickly as not to have its potential momentarily dropped, it must have the necessary amount of electricity already stored in condensers connected directly to the circuit. In commercial plants the place of such condensers is supplied by other live lines connected to the bus-bars.

The strain of double potential produced by charging a line has an interesting analogy. If a piece of metal be tested for tensile strength by suddenly applying a weight on the end, a double strain will be momentarily given the metal due to the slight motion of the weight allowed by the stretching of the test sample. In this case the inertia of the weight corresponds to the inductance through which the line is charged.

The discussion so far assumes that there are no losses of energy in resistance or in currents set up in adjacent bodies. Such losses, which always exist to some extent, tend to reduce both the amplitude and the number of oscillations.

CHARGING A LONG TRANSMISSION LINE

In the case of a long transmission line, however, the line cannot properly be considered to be a simple condenser, for this is equivalent to the assumption that the line is so short that its inductance is practically zero, and in actual long lines such is not the case. To present such a line, however, we may take a succession

*This rise of the line to double potential on charging was mentioned in Mr. Steinmetz' paper before the A. I. E. E., August, 1901.

of choke coils and condensers connected in series, as in Fig. 1. Consider a single line wire open circuited at the receiving end.

The "dead" line is to be charged at the end, *B*, from the high-tension bus-bar, *A*. Assume that, as the switch at *A* is closed, the point *B* is instantaneously raised to full potential. If now the line extended no further than the condenser *C*, we would have the case of a short line which has just been discussed; that is, the line will rise to double potential and oscillate until it finally settles down at normal potential. But since the line shown in Fig. 1 does not end at *C*, as soon as the potential of condenser *C* begins to rise, current begins to flow to condenser *D*, and as *C* rises higher and higher, more and more current will flow to *D*. The potential of *D* then begins to rise, which starts current to *E*, etc. As *D* rises slowly at first, *C* reaches bus-bar potential before *D*, and similarly *D* before *E*, etc. As soon as *C* reaches this potential it remains constant. At the same instant that *C* reaches bus-bar potential the current value in the coil between *B* and *C* reaches a maximum and becomes constant. Similarly with the current in the other coils. This final current, which appears in more and more coils as the line charges up, supplies the charge that is being added constantly at those points where the potential is changing, to continue the process of charging; though the potential of *C* remains constant, that of *D* continues to rise until it reaches the same value as *C*, when it, too, becomes constant, though the potential of *E* continues to rise, and so on along the line. Similarly with *E* and *F*, but each successive condenser reaches its maximum a little behind those nearer the point *A*, so that the net result is a wave of e.m.f. starting at the point *B* and passing along the line.

The general distribution of the potential of the line, showing the wave form at short intervals of time after connecting on the line is shown in Fig. 4.

This wave passes along leaving the lines fully charged. If the line be infinitely long it will experience no further disturbance, and if there are no resistance or other losses the wave will pass along at an infinite distance, keeping its form and raising in turn all parts of the line to the full bus-bar potential. If there be considerable losses of energy as the wave proceeds (as there usually are in any actual circuit), this wave will lose its shape somewhat, and will get feebler and feebler, until, if the line be long enough, it ceases to be perceptible. This dying away of intensity may be slow enough in commercial lines, so that a large part of the original

intensity of the wave will remain when the end of the line is reached. Now, the end of the line is open circuited, and the wave of electricity can go no further and is reflected back. At the reflecting point the maximum potential is twice that of the wave.

On being reflected, the wave immediately starts back along the line, leaving it charged to double potential (assuming no losses), and finally reaches the starting point, *A*, where its energy is absorbed by the bus-bar. But the line cannot stay at double potential, and a second wave is sent along the line, bringing it back to normal potential again. This second wave will be reflected at the open end, and will return again, but this time dropping the potential of the line to zero until, as the wave reaches *A* again, the line is practically in its initial condition. This wave, in turn, is absorbed by the bus-bars, and the whole series of operations gone over again and again. If, however, there are resistance and other losses, the wave is growing thinner and thinner all the time, and finally dies away, having only partly charged the line. As the wave dies down by the resistance losses, an infinite number of small supplementary waves are sent out, which complete the charging of the line. If there are no losses, however, no supplementary waves will be formed.

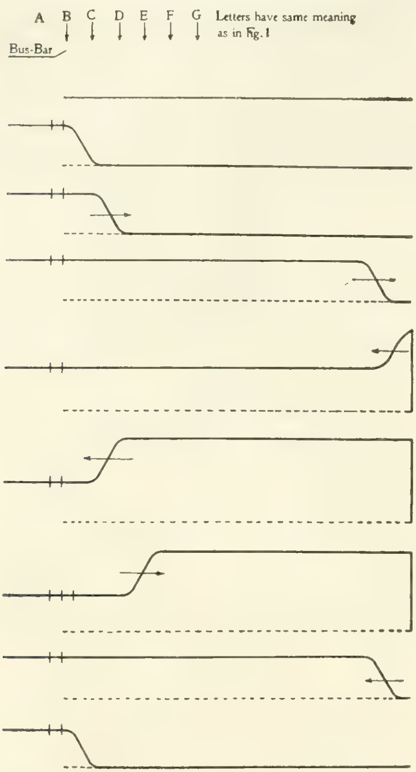


FIG. 4—CHARGING WAVE IN A LONG TRANSMISSION LINE

It will thus be seen that the charging of a long line is much the same as a short line; in both cases the line oscillates between zero and double voltage until the losses cause it to settle down at normal potential. These wave changes are indicated in Fig. 4.

Actual tests on commercial transmission lines suddenly charged

have shown a rise of potential much greater than normal at the end farthest from the switching.

Suppose a stretched flexible cord fastened at one end and held in the hand at the other. A quick motion of the hand sideways will send a loop or wave along the cord, which will pass to the end, will be reflected back and will finally reach the hand again. This wave is analogous to a static wave in the transmission line.

CHARGING A BRANCH LINE

Consider a line consisting of two parts, the more remote having a much smaller capacity and larger inductance than the nearer. When a wave starting from the beginning reaches the junction it will be partially reflected, since the whole charge of the large line cannot be crowded into the capacity of the small line, especially in view of the increased inductance of the new portion; that is, there will be a rise of potential at this point and a wave smaller than the outgoing wave will start back. As the original wave will not be wholly reflected, the potential at the juncture of the two circuits will not be double the charging voltage.

But a wave will also be sent forward into the second part of the line, which will have a crest as high as the maximum of the potential at the reflecting point. Therefore, at the end of the second line, when another reflection occurs, the crest of the last wave will be doubled. The resultant potential at this point will thus be very high, but not over four times the original voltage of the bus-bar. It may be much less. This means that a branch line at the end of a main system (especially if the latter consist of two circuits in multiple) will receive a very severe shock at the farther end when a wave enters it from the main line. This is a case that may readily occur in actual plants and should be carefully considered. If there be a third line at the end of the second, leaving a still less capacity and still greater inductance, a wave will be formed in this line whose crest has the value of the maximum rise of the reflecting point at the end of the second section of line, and which will double its potential at the farther end as before. This last rise of potential has as its maximum theoretical limit eight times the original charging voltage, but would actually always be much less. This case is very unlikely to occur in actual circuits. The total energy in the waves in the second and third sections of lines is much less than in the original wave, but is at a higher potential.

To return to the consideration of the uniform circuit. It has

been shown that when one end of a long line is suddenly raised to a certain potential and maintained there, a wave of charge passes along the line, leaving it charged, and that when this wave reaches the open end of the line it is reflected and produces all along the line a potential double that of the bus-bar. If, however, a sine e.m.f. be momentarily applied to the lines so that the end of the line is not maintained steadily at the full potential as before, but is immediately lowered, a wave will be found in the line as before, with the same maximum voltage but a different form. (See Fig. 5.) This wave leaves the line uncharged. The rise of potential at the reflecting point, however, is the same as long as the crest of the wave is the same, but in this case only the reflecting point receives double potential (assuming that only a single wave is sent into the line).

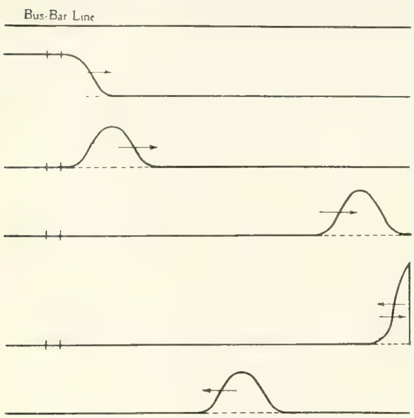


FIG. 5—CHARGING WAVE IN A LONG TRANSMISSION LINE—SINE E.M.F. MOMENTARILY APPLIED

If a wave be started at one end in a very long, narrow trough of water, it will proceed the length of the trough and on reaching the end will be reflected and will rise up to double height at the reflecting point. This wave in the water is again analogous to the wave of charge passing along the line, leaving it unchanged and causing a double strain at the reflecting point.

In all cases of static effects the change in e.m.f. of the busbars due to the generator is so slow that the generator e.m.f. may usually be considered constant while the static phenomena are taking place.

The length of the wave in the line is determined by two factors —the speed at which the charge passes along and the time required to bring the potential of the first point of the line to its full value; it is the extreme distance to which the charge has penetrated when charging potential becomes stationary.

If the line is shorter than the length of the wave no complete wave will be formed, but reflection will produce the same rise of double potential at the end. The speed at which the wave will pass

along the line is inversely proportional to the square root of the product of the capacity and the inductance per unit length (unit length equals one earth quadrant=6 200 miles)—that is, to the time constant. But on air lines the waves travel at approximately the speed of light, so that there is an inherent relation between the inductance and capacity of an air line which at first thought is very surprising. This relation is expressed in general by the equation $v = 1/\sqrt{LC}$, or $L = 1/v^2C$, where v is the velocity of the wave in air.

Evidently the more sudden the disturbance the more likely is the formation of a complete wave. In the extreme case when the length of wave is very much longer than the line (as in the case when the voltage is applied to the line very slowly) there is practically no wave formed and we have the plain charging of a condenser. This is also the case considered in discussing the charging of a short transmission line.

If the source of e.m.f. from which the line is charged cannot maintain rigidly its potential during charging, the line will be charged up by steps as already explained. The result is that a weaker wave is obtained, followed by a second wave as the bus-bar recovers its potential, which completes the charging of the line.

CHARGING AN UNDERGROUND CABLE

What has just been said of charging a line applies equally well to an underground cable, except that the cable has a much larger electrostatic capacity and a smaller inductance than the transmission line. If a wave be formed in charging the cable, this wave will be reflected at the end, causing double potential all along the cable as it returns to the starting point. If, however, the cable is so short that no wave is formed, the cable will be charged like a short line, that is, as though it were a condenser. As before, if a momentary impulse up and down be given the cable instead of a steady charging voltage, a wave of the form shown in Fig. 5 will be produced, which causes double potential at the end of the cable.

If a steady alternating e.m.f. is applied to a transmission line, waves will be sent along having crests of positive and negative values alternately and will be reflected at the end of the line one after another and return toward the starting point. When a returning positive crest meets an advancing positive crest, double potential will result at the point of meeting; similarly with two negative crests. When a positive and a negative crest meet, zero potential will result at the point of meeting. The result is the forma-

tion of nodes and loops in the line or cable, that is, points of zero and of double potential as shown in Fig. 6, where advancing waves are shown full, reflected waves dotted, resultant nodes and loops in dot and dash.

The waves sent into the line by the alternating e.m.f. are in continuous motion back and forward, but the nodes and loops are fixed in position, though the loops vary in length, alternating between positive and negative. This phenomenon is similar to the formation of nodes and loops in an organ pipe. There is always a loop or point of high potential at the reflecting point. The distance between two positive loops at any instant is the wave length of the moving waves.

To this point the lines and cables have been considered as open circuited at the farther end. Comparatively little difference will

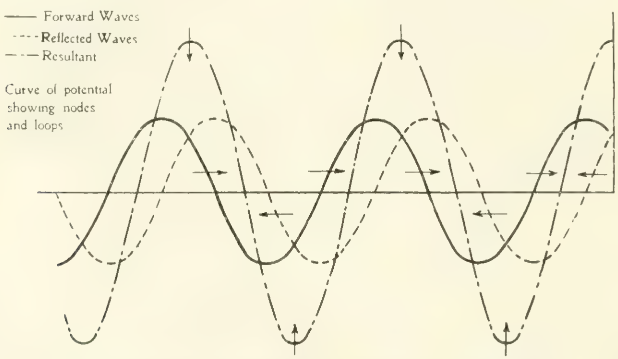


FIG. 6—NODES AND LOOPS IN A LONG LINE OR CABLE

result in static effects, however, if they be closed through transformers at various points, for the inductance of the transformer winding is so great that the comparatively large quantities of the charge on the line would not be materially lessened by the electrostatic capacity of the transformers. In fact the transformer is subjected to a very severe strain without its being able to relieve the line. This strain is similar to that produced by connecting a "dead" transformer to a live line, since the rise of potential of the transformer, due to reflecting the wave, may be very abrupt.

OPENING A HIGH-TENSION CIRCUIT

When opening a load current in a high-tension line or cable, no rise of potential will result unless the current be suddenly interrupted. With such an interruption, of course (as all commercial circuits contain considerable inductance), a rise of potential will

result, its severity depending upon how suddenly the current is interrupted, how much magnetic energy is stored in circuit, and how much electrostatic capacity exists in the neighborhood of the break. This matter was treated by Mr. Steinmetz in his paper before the American Institute of Electrical Engineers in August, 1901. He there states that an excessive rise of potential may result from the interruption of short-circuits. As a matter of actual experience, it is the opinion of the author that little rise of potential actually occurs from the opening of load or short-circuit currents in commercial systems, as the resulting arc cannot drop out suddenly on account of the great amount of heat generated. There are often, however, other causes of static strains which may result from short-circuits, that occur at practically the same instant of time, and in some cases the results of one cause may be assigned to the other.

However, by opening an unloaded line or cable, it is entirely possible to obtain a rise of potential as follows: On opening a switch to cut out an unloaded line, the arc of the charging current tends to drop out when the current strength is zero, that is (since the unloaded line takes a leading current) when the voltage is a maximum; for as the line will momentarily hold its charge there is at this time little difference of potential between the line and bus-bars, even after the switch is opened. The line is thus left charged when the switch is opened, while the potential of the bus-bars is changing with the generator e.m.f. When the voltage of the generator has passed through one alternation there will be a potential between the line and bus-bars, which may be sufficient to cause the arc to establish itself again and recharge the line. The arc will again drop out when the current becomes zero, and this action may be repeated several times before the line is finally clear. The sharp crackling sound often accompanying the switching out of a high-tension line or cable suggests this phenomenon. This recharging of the line will cause the formation of a wave and the consequent rise of potential as in the case of charging a line. Thus, pulling off an unloaded line may have the same effect as charging it so far as the static rise of potential is concerned.

In the case where one terminal of the single-phase generator is grounded and charging current to a line is opened at the other, a static wave may be produced in the line of double the intensity caused by charging the line "dead," that is, a wave of double line voltage, giving a maximum rise of potential of four times normal.

(To be continued)

SQUARES AND CUBES*

R. A. PHILIP

STRENGTH varies as the square, while weight varies as the cube of the linear dimensions. As weight and strength are fundamental features of machine design, every machine and every part of every machine is affected. A rope supporting a weight is a direct illustration. Compared to a weight and rope of one-half the linear dimensions the original rope which is four times as strong is called on to support eight times the weight. As the size increases the disruptive forces due to weight gain on the resisting forces proportionately. At some point a critical dimension will be reached at which the forces will be equal. Above this point the strength will be insufficient to support the weight.

Beams furnish good illustrations of this principle. A beam if sufficiently long will break under its own weight, while a small scale model will support both itself and additional load. Bridges are great complex beams built up of combinations of little beams, ties and struts. The strength of each beam and tie and strut is proportioned to the square of its lineal dimensions while the weight of each separate part and of all the other parts supported by it is as the cube of the same dimensions.

Buildings are also constructed of columns and beams and consequently follow the same law. The heighth of buildings has increased from ten to twenty and fifty stories. From fifty to a hundred stories is a step that would require more than courage were there reasonable doubt of resulting strength and safety. But if a doubt exists it can not be removed by the construction of a small model, for the model may safely stand though the building fall under its own weight before half its height is reached.

Machines have the same elementary parts. Beams and columns at rest constitute the frame, others in motion are the working parts. Perhaps shafts constitute the most characteristic feature of machinery, being used in profusion in watches, engines, vehicles, printing presses and other contrivances, and every shaft is a beam.

In a vertical engine and a small model of the same engine the same steam pressure will produce the same unit stresses in the pis-

*By permission from the *Stone & Webster Public Service Journal* for November, 1909.

ton rod, but the resultant upward pressure on the bearing caps will be vastly different. In the model the cap must be securely fastened to hold the shaft down against the pull of the piston rod when the steam is acting upward, in the engine the weight of the fly-wheel may be sufficient without the aid of the cap.

This example brings out the curious feature that while the principle of squares and cubes usually works in favor of the model and against the machine, there are exceptions where the reverse may be true and a model may fail though the machine may work.

Small machines and large machines require parts of different proportions. To attempt to build a line of engines, say a one horse-power, a two and a five horse-power, and so on up to fifty horse-power, all from the same drawings by merely increasing all of the dimensions in a uniform proportion would result in failure. Manufacturers frequently exhibit a line of engines or pumps or other machines that have such a close family resemblance that a superficial view would lead to the conclusion that such a plan had been followed. A careful examination of a well-designed line will show, however, that the differences are as important as the similarities. The general design of a line of machines is that suited to the ones of mean size. Here the general proportion of shafts, bearings and other parts is very good; as the extremes are approached these proportions get worse; finally the general design becomes so unsuitable that a revision is necessary.

Animals are also machines and their structure must conform to the laws of machine design. Voluntary locomotion is one of the important characteristics of animals, and for this purpose those which use the surface of the earth for travel are provided with legs. Primarily the legs are columns, which must be strong enough to support the weight of the superimposed parts. As with other structures the strength of these columns is as the square, while the weight supported is as the cube of the linear dimensions. Nature has strengthened those which were too weak and pared down those which were unnecessarily strong, until each animal is fitted with a very close approximation to its exact requirements. Now doubtless the legs of an ant are in due proportion to the size of its body, with a proper factor of safety but no needless surplus. Were an ant to be created as large as an elephant its linear dimensions would be increased perhaps a thousand fold and while its legs would be a million times stronger its weight would be a billion times greater. It could not even stand; much less walk.

The scale of walking creatures from the ant to the elephant shows a progressive increase in the relative thickness of the legs. Were there an animal as much larger than the elephant as it exceeds the ant, the problem of supporting the immense weight probably could not be solved by the quadruped design which seems standard for large land animals. Such a creature would have to be supported according to a radically new plan and would resemble no creature of which we have knowledge.

As with manufactured machinery the range from the smallest to the largest is divided into well defined lines each suited for a limited range of sizes and designed according to a common plan. Certain sizes can be built to either of several plans, while others allow of but one good design. These principles are illustrated by the relative ranges in sizes found in insects, birds and quadrupeds.

In flying the weight must be sustained by the excess pressure of the air under the wings. For any given design the wing surface will vary as the square of the size, while the weight will vary as the cube. The proportion of wing surface to weight becomes very favorable when sizes are small. Insects consequently find the problem of flying very simple. Wings can apparently be attached to any desired shape of body, and a complete set of legs in addition does not interfere with the efficiency of the arrangement. In birds the ratio is much less favorable and the whole structure must conform to rigid conditions to make efficient flying possible. Even so, the larger birds easily lose proficiency and the very largest can hardly be said to fly at all.

Absolute size governs design. If you take a beast or an automobile and double every linear dimension the design will be wrong, the legs and the axles being disproportionately weak for the increased weight; if you decrease by half every linear dimension the design is also spoiled, for now the legs and axles are unnecessarily heavy and clumsy. The size governs the proportion and conversely the proportion must determine the size. In order that the supporting parts be neither too strong nor too weak for the parts above, a given design must be executed to a suitable scale. Thus the proportion of parts found in an elephant is unsuited either to an animal of ten times the size or to one of one-tenth the size.

The conclusion is that in machines, static or dynamic, natural or artificial, size and proportion are correlated; given one, the other follows from the principle that strength is as the square while weight is as the cube of the linear dimensions.

THE JOURNAL QUESTION BOX

This section of the Journal is open to our readers. Questions should preferably deal with matters of general interest; they should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

397—Resistance for Charging Storage Battery—Please give either specific or general information regarding the method of determining the proper resistance to use in charging a storage battery of 44 cells. The normal discharge rate for the battery is 70 amperes for four hours, and the charging rate 50 amperes at the start, followed by a charging current of 20 amperes for finishing. The source of power is a 125-volt direct-current circuit.

S. S. V.

The formula which applies to the charging of storage batteries is $R = \frac{E - e}{A}$ in which R = the required resistance, including the resistance of the line connections; E = line voltage, e = battery counter voltage, and A = charging rate in amperes; thus, for an initial charging rate of 50 amperes, the required resistance = (125 — 95) ÷ 50 = 0.6 ohms, and for a finishing charging rate of 20 amperes, the required resistance is (125 — 112) ÷ 20 = 0.65 ohms. If the line voltage is maintained at 125 volts under load, the resistance of 0.65 ohms will give an initial rate of 45 to 50 amperes, which will gradually decrease to about 20 amperes as the battery voltage rises to 112 volts, i. e., 2.55 volts per cell.

H. M. S.

398—Circuit Breakers in Series—A prominent local power company uses several circuit breakers in series, on the high-tension lines. Is this practice to be recommended on an installation of 10 000 to 20 000 kw. capacity at 10 000 volts, or is one breaker sufficient? What type of circuit breaker is recommended for this service?

H. W. K.

This question is closely related to No. 301, Sept. '09. There are oil circuit breakers on the market which will handle 10 000 to 20 000 kw at 10 000 volts more or less successfully, depending upon the location of the circuit breakers relative to the source of power. The practice of using two or more circuit breakers in series may be followed for several reasons. First, the operators may have found that one circuit breaker alone would not successfully clear the line under all conditions, whereas two would accomplish this without difficulty. Second, it may have been found that much more continuous service is obtained by having two circuit breakers so arranged that, if one is damaged in any way through opening a short-circuit, the damaged breaker can be eliminated and the second one depended upon for protection while repairs are being made. Third, the circuit breakers may be so located with respect to the various feeders that certain sections of the line can be cut off without affecting the remainder of the system.

H. G. M.

399—Repairing High Voltage Lines—We have a high potential system here in Hawaii in connection with which there has been considerable trouble due to charred insulator pins which have caused poles to burn down and many shutdowns of the whole electrical plant. I read in the JOURNAL about Mr. J. S. Jenks' method of repairing high voltage lines while in service. Would it be possible to repair our transmission lines, which carry 33 000 volts, 25 cycles, three-phase current, by the same method? If possible, please state where we could purchase such devices as insulator clamps, insulated screwdriver with hook,

insulated wire cutters, etc. With how high a voltage can a man standing on a dry pole safely touch the wire with his bare hands? M. T. C.

We do not wish to be understood as recommending this method, as live line repairs are highly dangerous unless made by careful and experienced men provided with tools and apparatus of positively known reliability. The apparatus which was used for this high tension work was entirely home-made. If you cannot get sufficient information from the article and editorial as printed, and the cuts, you should hardly undertake such work, and we would advise you not to run any undue risk. It is not at all safe to stand on a pole and touch the wire, as you have no way of determining whether the pole is dry or whether or not there is sufficient moisture in the heart of the pole to give considerable ground. J. S. J.

400—Size of Car Wheels and Railway Motor Operation — What results would be expected regarding maintenance of motors, speed and power consumption, if a four motor car were operated with different sets of wheels, varying in diameter from one to four inches, all other conditions remaining normal? W. G. P.

If all eight wheels on the car were changed simultaneously, so that each wheel would be larger in diameter—for instance, four inches larger than it was originally—the speed of the car would be higher with a given voltage and the power consumption would be greater. If the wheels on the car were of different diameters, so that the wheels attached to No. 1 motor, for example, were four inches larger in diameter than any of the other wheels on the car, then No. 1 motor would take more than its share of load, and the other motors less than their share. However, this would have comparatively little effect on either the speed or the power consumption of the car, as a whole. If three pairs of wheels were four inches larger in diameter than the fourth pair, the motor attached to the fourth pair would receive less than its share of the load, and the speed and power consumption of the car would be increased somewhat, but not as much as if all four pairs had been increased in diameter. C. R.

401—Drop in Alternating Current Circuits—A 220-volt, two-phase, 60 cycle circuit consisting of 1 000 000 circ. mil. conductors 15 inches apart, carries current 800 feet to induction motors aggregating 450 hp., in various sizes, which operate under practically full-load conditions. The voltage at the motors is about 130 to 140 volts. On a basis of ohmic drop the transmission loss should be very small. What is the matter? C. W. D.

The difficulty probably arises largely from the attempt to decrease the drop by increasing the size of copper in the circuit, without sufficient sub-division of the conductors. This is largely due to the fact that on alternating-current circuits supplying loads of relatively low power-factor, self-induction of the circuits forms the controlling factor in the total drop, and that the inductive element is only slightly reduced by increasing the size of the conductor. For the elementary principles involved and the method of calculating the drop, see articles in the JOURNAL for February and June, 1906, and March and April, 1907. In the latter article the largest size of wire given is 300 000 C. M. for 60 cycles, as larger sizes give excessive inductive drop. Even with conductors of 300 000 circ. mils., when the wires are 18 inches apart and the power-factor is 85 percent or less, the total drop is more than two and one-half times the ohmic drop. From a few preliminary calculations it would seem that, if the total drop is to be reduced to reasonable proportions, it will be necessary to divide the circuit into at least as many as four two-phase circuits, each conductor of which would consist of one No. 0000 or No. 000 B. & S. copper conductor,

the conductors of each phase of each circuit being arranged, if practicable, at the opposite corners of a square. It is estimated that this arrangement will give a total drop of about 56 volts, assuming an average power-factor of 80 percent and an average efficiency of 75 percent. Wires carrying current in opposite directions should be placed as close together as practical, and those carrying current in the same direction should be separated. If the transformers have suitable taps, it might be advisable to raise the voltage to 250 volts at the transformer terminals, which would give approximately 200 volts at the motors when the size and arrangement of conductors proposed above is used. It is unfortunate that the voltage of the circuit is so low and that the distance is so great. C. P. F. & C. F. S.

402 — **Capacities of Motors Required for Operation of Machines, Presses, Etc** — Is there information available telling how to estimate the proper capacities of motors for use in driving various machines, presses, etc., giving also the proper allowance to be made for friction in belt and shafting? D. F. S.

This is a matter to which much attention is being given among manufacturing companies and consulting engineers. Through the accumulation of specific information it is believed that quite reliable general information will eventually be available. It will readily be appreciated that questions of motor capacity requirements can not be solved by formula; information must be obtained by experience on account of the fact that the conditions of operation vary over wide limits with various kinds of machines and with given machines on different kinds of work. In an article by Mr. A. G. Popcke, in the JOURNAL for Nov., 1909, p. 674, some valuable suggestions are given regarding the application of the graphic recording type of meter in determining just such information. For power requirements on printing machinery, see No. 172, in the JOURNAL for Nov., 1908. Several interesting articles are under preparation, giving the data and methods for determining the power requirements of various motor applications, which will probably appear in early issues of the JOURNAL. In this connection see the Six-Year Topical Index for various articles in previous issues of the JOURNAL. Note especially "Mechanical Considerations in the Application of Electric Motors," by C. B. Mills, May, 1909, p. 281.

D. E. C.

403 — **Horse-Power for Elevator Motors**—How is the horse-power for elevator motors figured? D. F. S.

Because of the extremely uncertain character of the load of elevators it is customary to determine the motor capacity experimentally. The usual procedure for a given case is for the motor manufacturer to furnish the company equipping the elevator with curves and other data covering the performance of motors of standard capacity approximating the probable requirements. It is then necessary to analyze the conditions under which the elevator is to operate, determine thereby the probable power required for operation, and then select a motor of the proper characteristics to suit the given case. H. D. J.

404—**Re-Winding Auto-Starter** — A 20 hp., three-phase, star-connected, core-type, auto-starter for an induction motor has been rewound with the proper size and amount of wire, but one phase of the transformer is wound in a direction opposite to that of the other two. The primary voltage is 440 and the secondary 176/374. What effect will this have on the operation of the transformer? C. B.

The probable effect of connecting such a transformer to the line with the winding on one leg reversed would be to burn out the windings on all three phases, as the flux in the reversed phase would oppose or "buck" the flux in the other two phases, allowing the exciting current to reach values that would be disastrous.

Normally, the middle section, for instance, provides a return path for the flux of the other two, and, in order that it may operate in this way, the windings must be in the same direction on all three cores. If one winding is reversed in direction, transposing the end leads will correct this fault except in regard to the voltage taps. In the case at hand if the end leads are transposed, the voltages on that phase will be 66 and 264 instead of 176 and 374, as on the other two phases. A. P. B.

405—Transformer Units of Different Ratio in Delta Connection—If three transformers, which are wound so that the secondary pressures are all slightly different, have their secondaries connected in delta, will a distortion of the phases result? E. F. K.

The effect of the different transformation ratios will be to set up an unbalanced e.m.f. on the secondary side which will be consumed in circulating a local current through both the secondary and primary windings. The circulating current will tend to equalize the secondary voltages. Under load, however, the effect of the different transformation ratios will be to unbalance the primary currents, the transformer with the smallest ratio having, of course, the greatest primary current. E. C. S.

406—Effect of Relative Position of Conductors on Inductive Drop—What percent of difference in drop results when the three conductors of a three-phase transmission line are in the same plane instead of being arranged at the vertices of an equilateral triangle? J. L. S.

The results for a specific case, calculations for which are outlined in No. 267, June, 1909, show an increase of drop of ten percent with the three conductors of a three-phase circuit arranged all in the same plane instead of in the form of an equilateral triangle. With line constants of different values, correspondingly different results will be obtained. The primary point to be noted is that the equilateral triangular arrangement gives the least inductive drop, as this is the only arrangement that entirely eliminates mutual induction.

NOTE—The following were omitted from the JOURNAL Question Box for January 1910:

376—Synchronizing Resistance for Rotary Converters—Please give the connections of a rotary converter in which resistance is used in one phase to assist in synchronizing, and explain the action. E. W. P. S.

A synchronizing resistance is always used in rotary converters supplied with starting motors. This resistance is connected across one phase and serves as a means of loading the machine in order to lower the speed during the process of synchronizing. The starting motor raises the speed of the machine above synchronism after which it is adjusted in this way. J. B. W.

377—Self-Starting Synchronous Motor—Please give connections of self-starting synchronous motor and explain the action of the motor at starting. What relative values of e.m.f. and current occur in the field and armature on starting? J. B. W.

Refer to article on "Self-Starting Synchronous Motors," by Jens Bache-Wiig, appearing in the JOURNAL for June, 1909, p. 347, and No. 76, May, '08, in which are outlined a number of features of design and operation of this type of machine. J. B. W.

378—Insulation of Conductors in Squirrel Cage Induction Motors—What are the advantages and disadvantages of using insulated copper conductors in the rotor winding of squirrel cage induction motors? C. C. H.

On small motors there is very little choice between bare and insulated rotor conductors and practice varies according to methods of manufacture. On large motors, where the voltage is appreciable from one end of the bar to the other, local currents are set up in the punchings when bare bars are used, which will reduce the starting torque, but will have very little effect under full-load running conditions. G. H. G.

THE

ELECTRIC JOURNAL

Vol. VII APRIL, 1910 No. 4

Steel Towers for Transmission Lines

When the telegraph was invented the problem was at once presented of carrying a continuous metallic conductor for many miles across country and at the same time keeping such conductor insulated from the ground and out of people's way. But two methods presented themselves—to carry the wires in an insulated conduit underground or to place them high in the air on wooden poles. It is interesting to observe that the method of burying the wires was attempted for the first telegraph line, but was soon superseded by a pole line. The latter method has become practically universal in telegraph work. When, later, electric power came into use, the same methods were adopted; the usual development followed in that the power conductors became heavier, the voltages higher, and consequently the insulators larger and more massive. The pole line for telegraph purposes has never been as reliable as could be desired but is perhaps as good as the capital charges will permit. With the introduction of power transmission, the necessity for reliability increased, if anything, while the increased stresses tended to augment the chances of failure.

Moreover, with wood structures no definite factor of safety was possible. The sight of a mile or more of poles broken off during a storm and the wires on the ground is calculated to impress one's mind with the uncertain and transient nature of the factor of safety of wooden poles. Thus steel was sought as a substitute, as a means of gaining both reliability and permanence. The advent of steel involved some fine adjustments both in the placing of material in the tower structure as well as between cost and excess of strength. While, in general, the earlier steel towers have been as satisfactory as could be expected there has been of necessity more or less of the cut-and-try process in the matter of determining the types of towers most desirable. The paper by Mr. W. K. Archbold, in this issue of the JOURNAL, well illustrates some of the recent forms of structural development to meet particular needs. The paper

also brings out prominently various special problems which are involved and indicates new mechanical conditions which arise when the length of spans is greatly increased.

The steel towers have been sufficiently strong, with very few exceptions, for the work they have had to do, but their use in the place of comparatively non-conducting wood has placed all the insulating responsibility on the porcelain insulators. The extreme stresses to which these insulators may thus occasionally be subjected and the resulting arcing and disturbances after breakdown have at times made power transmission on steel towers a disappointment.

The improvements that have been made in insulators and in methods of guarding them from destructive arcing and the better provison that can now be made for cutting out a defective section of line by means of selective relays and circuit breakers, have made the outlook for power transmission on steel structures much brighter. An interesting development in the direction of protection of insulators from destructive arcing is described in a paper presented by Mr. L. C. Nicholson before the Charlotte (N. C.) meeting of the American Institute of Electrical Engineers, March, 1910.

To one looking down lines of steel towers stretching over distant fields and hills the impression is certainly one of ruggedness, reliability and permanence, as compared with a line of slender wooden poles. It is to be hoped that this impression of strength may speedily be justified with reference to the electrical features as it is now with regard to its mechanical reliability.

R. P. Jackson

Cost of Stops for Heavy High-Speed Interurban Cars

An important matter that is well understood but is frequently not given proper consideration in electric railroad work, is the cost of stops and of high speed service with heavy cars. This is especially mentioned because there have been some striking instances in which certain roads seeking to make fast time, together with frequent stops, have operated schedules that necessarily must be more costly than were warranted by the benefits that were secured by high speed. Frequent stops should not be made with cars that are run at high maximum speeds between stops, or that are excessive in weight. It is impossible in a short statement to go into this subject in any comprehensive way, and no definite rules can be laid down to determine the relative cost and advantages derived by local stops, but a simple statement of the

operating speeds of some modern electric roads, together with the stops they make, the weights of cars and current consumption entailed by the stops, is enough to show how ill-advised they are.

Take the cases of electric roads, of which there are a number, that use cars which weigh, with their equipments, 50 to 60 tons each, and that run these cars at maximum speeds of about 60 miles per hour, and that make frequent stops under these conditions and even flag stops. For stopping heavy high-speed cars the cost of the power consumed per stop is by itself excessive in comparison with the profit that can generally be made by reason of a local stop or say a flag stop. A car approaching a flag stop at 60 miles per hour will rarely see a flag signal before it is necessary to apply the brakes to make the stop. The result is that the car must be braked down to a stop from 60 miles per hour, and to restore the speed to 60 miles per hour after the stop requires, for a 55-ton car, six to seven kilowatt-hours in addition to the power needed to overcome the friction of the car. In other words, six to seven kilowatt-hours are used to supply the kinetic energy due to the speed, which energy is expended in heating the brake shoes and machinery, and other friction losses every time the car is stopped by braking from 60 miles per hour. Under these conditions the cost of electric power alone for making the stop materially reduces the profit on a 10-cent or a 20-cent passenger fare. The cost of other items than power for stopping a heavy, fast car, such as wear and tear on machinery and brake shoes, loss of time when fast schedules are desirable, and the interest charges on the extra heavy machinery and equipment that have to be used to make fast local schedules, generally exceeds the cost of the power consumed by the stops, so that the total cost of stops under such conditions is out of all proportion to the benefits and earnings secured by them.

Compare the above with the cost of stopping a lighter car, say of 35 tons total weight, that makes a maximum speed between stations of say 48 to 50 miles per hour. Approaching a flag station at these speeds a motorman can usually see a flag in time to cut off power and coast down to say 45 miles per hour before applying the brakes. To restore this speed after a stop requires, for a 35-ton car, only 2.2 to 2.5 kilowatt-hours of electric power to supply the kinetic energy expended when the car was stopped; and other expenses entailed by stops are likewise reduced.

F. Darlington

An article by Mr. Frederick W. Taylor was published in the JOURNAL for September, 1909, under the heading "Why Manufacturers Dislike College Graduates." This article was from a stenographic report of a discussion given before the Society for the Promotion of Engineering Education, and was published before Mr. Taylor had revised the material for the proceedings of the society. While these revisions brought out Mr. Taylor's meaning more clearly and corrected some slight stenographic errors, the article as published was received with widespread interest. In addition to numerous comments on the article, a number of magazines have reprinted it, one of them being a Russian electrical paper, the translation being made by V. Y. Peskoff, of Moscow. The latest reprint of the article which has come to our notice is contained in *The Sibley Journal of Engineering* for February, 1910. In the editorial columns of the March issue of the same publication the following comments on this article are given by Mr. L. A. Osborne, an alumnus of the Sibley College, Cornell University, class of 1891, and now second vice-president of the Westinghouse Electric & Manufacturing Company:—

Graduate Apprentices in Specialized Industries

I have long been interested in the matter which Mr. Taylor discusses and regard his paper as a distinct and valuable contribution on the subject. I think that if one takes the field of manufacturing broadly, Mr. Taylor's generalization that manufacturers do not care to employ college men is probably true in a large majority of cases, but if one considers the more highly specialized manufacturing industries, which depend for their success on applied science, then I think that the reverse is true. Manufacturing is such a wide term and encompasses such a variety of conditions that it is improper to draw too broad generalizations therefrom.

Again, it is proper to differentiate between the varied activities of manufacturing and not to judge the situation wholly from the standpoint of the manufacturing departments.

It is an undoubted fact that large manufacturers find it difficult to interest college men in the purely shop work; a field, however, which would well merit the attention and study of educated engineers. That more college graduates have not devoted their attention to shop practice is due to the fact that larger opportunities have existed in the engineering and commercial fields, but it will only be a question of time when an increasingly greater number of engineers will find their permanent work in the shop organizations.

I fully agree with Mr. Taylor in his criticism of the deficiency in the point of view of young engineers, but I do not see that this criticism applies any more to the men who have taken four years additional college work than to the boy who terminates his educa-

tion at seventeen or eighteen after a high school course. In either case the individual has been in the position of being a recipient of knowledge and the moment he takes up work for pay, he is in the position of a giver of service and the limitations in one case are only perhaps exaggerated in the other by the fact that the individual has been in the position of absorbing knowledge a little while longer than the other man and the habit is more fixed. Each one has to learn that the keynote of success is personal service; and in my experience I have found that the college man, with broader culture and higher intellectual attainments, is quicker to adjust himself to these new conditions than his less fortunate brother.

I will pass over the points in Mr. Taylor's paper which speak for the improvement in the training of men, for it is obvious that in so far as the student can be impressed with the importance of application and of devoting his life to the giving of service, to that extent he is better fitted to the task which he takes up when his college career is closed. That is a problem of the educator, but withal a most important one.

Mr. Taylor places intellectual ability as third in the list of desirable attributes. While I agree that mere intellectual brilliancy is of little use without the balance offered by character and sincerity, yet I place intellectual ability as not the least important quality of a useful man. Intellectual superiority does not pre-suppose intellectual arrogance, but quite the reverse. What employers require are young men of sound intellects, of good habits, of serious ambition, without the belief that the world owes them a living, and with a firm determination to give more than they receive. Men with such qualifications will be valuable assistants and employees. With the advantage of an engineering education, they are essential to future industrial and business development. Lacking these essentials, all the education in the world will be unavailing.

After all, education, be it engineering or otherwise, is not magical in its effects. Human nature is much the same the world over and educated engineers are not different in the aggregate from others. We have come to expect more of them, however, and it is the duty of their teachers to impress them with the fact that with their better estate come binding obligations to their fellowmen; that all through life more will be expected of them than from those who have not had their advantages, and that they will be successful just in the degree that they meet their obligations.

L. A. Osborne

STEEL STRUCTURES FOR HIGH-TENSION TRANSMISSION LINES AND SPECIAL CROSSINGS

W. K. ARCHBOLD,
President, Archbold-Brady Company

THE use of steel structures in place of wooden poles for electrical purposes has increased rapidly in the last few years, both on account of the scarcity and increased cost of suitable wooden poles and of the desire for a more permanent and better construction, and also in many cases on account of the necessity for heights and strengths of structures, spacing of wires, etc., which could not be obtained with wooden poles.

In the design of these structures the following elements should be considered:—A suitable clamping arrangement for the cables, which can be properly insulated and is of sufficient mechanical strength to transmit the strains which come through the cables to the structures; the supporting structure and the foundations.

These elements should all be taken into account, as they are of equal importance. As an illustration of the first element, a method of dead-ending a 60 000 volt, three-phase line in each direction from a sub-station where the line is carried in and out, is shown in Fig. 1. The insulators are cemented to high strength cast steel or malleable iron pins. In this case the pins are flat on the bottom. Metal caps, which are flat on the top, are cemented to the tops of the insulators. To these caps a plate is bolted and to the plate are bolted clamps holding the ends of the cables. Usually the pins and insulators may be of the same type as those used on the line structures and the arrangement is special only in the caps and the clamps where more than one insulator is required to hold the strains.

Another type of construction, using strain type insulators for carrying the strain, with a jumper up to a pin type insulator from which the line is carried on, is shown in Fig. 2. This arrangement is that specified by the New York Central & Hudson River Railroad for high-tension lines crossing their tracks.

There has been a great diversity in the design of transmission structures and two distinct ideas have been carried out in such designs. A number of these structures have been built by manufacturers of wind-mill towers and the usual wind-mill practice has been followed. While some have been sufficiently substantial and reliable, others have been designed with the idea of saving weight,

and cost has been kept too prominently in mind. These towers should be built to a reasonable structural specification, and the minimum sections should be angle irons not less than one-fourth inch in thickness, standard channels and beams, and rods not less than one-half inch and preferably five-eighths of an inch in diameter. Connections for rods should be such as to allow for adjustment. The standard practice of the writer's company has been to use clevises for such connections, the rods and clevises being cut with right and left threads, so that the rods can be adjusted by the use of a Stillson wrench. Bolts should be not less than five-eighths and preferably three-fourths inch in diameter and wherever possible two bolts should be used at the connections, except the pin connections.

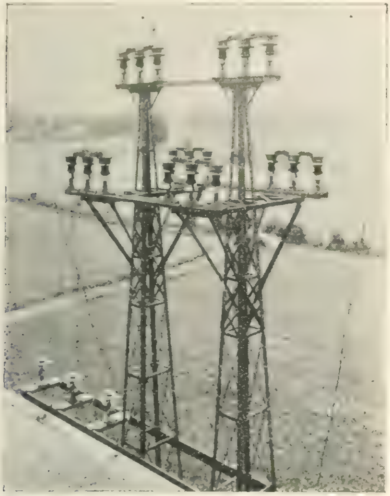


FIG. I—DEAD-ENDING TOWER AND TAPPING-IN ARRANGEMENT FOR HIGH-TENSION LINES AT SUB-STATION

In some parts of the country the steam railroads are requiring steel structures to support high-tension transmission lines carried over their tracks. Some of the roads are issuing specification requiring that the plans of the crossing structures, with shop details, be submitted to them for their approval. The railroads sometimes impose requirements which are undoubtedly more rigid than necessary, as the plans of the structures are usually sent to bridge engineers for checking and their tendency is to require the same class of construction that would be required for railroad bridges, which, in

FIG. 2—TRANSMISSION LINE TOWERS FOR CARRYING 60 000-VOLT CIRCUITS OVER RAILROAD TRACKS

many cases, leads to unnecessarily expensive structures.

Towers carrying overhead wires are probably subject to greater overturning elements than any other type of structure, with the possible exception of a water tower with the tank empty. The cables on a long river crossing, such as shown in Figs. 3 and 4, will produce

FIG. 3—TRANSMISSION TOWER FOR RIVER SPAN

FIG. 4—SIDE VIEW OF TOWER FOR RIVER SPAN

This span is 1 475 feet long. The towers carry an 11 000-volt, three-phase circuit, the conductors across the river being 7/16 inch plow steel strand. The strain of each conductor is shared equally by eight insulators. The location was such that the towers could not be guyed, and they were designed for a working load of 8 000 lbs. per wire, or 24 000 lbs. total.

a continuous overturning moment resulting in an uplifting force on the foundation on the side away from the long span. Ordinarily the wires leading away from the crossing will be slack to the next support, so that the structures themselves with the foundations must take care of these strains. These strains will be greatly increased,

of course, if wind and sleet come on the wires, and great care must be used in the design of the foundations to allow an ample margin for such strains.

There has been a great variety of opinion as to the possible strain which may come from wind and sleet loads. The observations of the writer and his associates, and the literature, specifications, etc., which have been gathered from many sources, indicate that a specification of one-half inch of sleet on the radius around the cable, with an allowance of eight pounds per square foot of projected area on the round surface for wind, is a reasonable assumption, as this is a load which may occasionally occur in some climates. Fig. 5 gives an idea of possible sleet loads. Some specifications take into account a heavier wind, perhaps as much as twenty pounds per square foot of projected area, but this is not apt to occur at the same time that the heavy sleet occurs, and the larger wind pressure on the bare wire will probably not produce as great a strain as the smaller wind pressure on the sleet-covered wire.

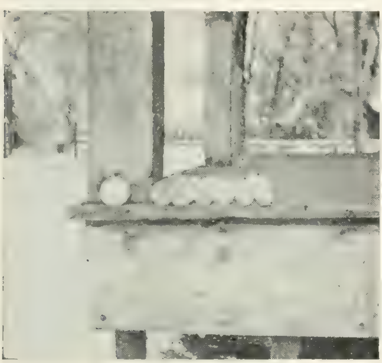


FIG. 5—SECTION OF SLEET REMOVED FROM WIRES OF TRANSMISSION LINE AFTER STORM

Illustrative of possible sleet loads. A comparative idea of the size of these pieces of ice is given by the watch placed at their left.

Structures for long crossings where the strains are considerable should be designed so that they will be economical in weight and so that they may be assembled and erected in the field with a minimum of labor. This latter point is sometimes not properly considered. Even the heavier structures for these purposes do not compare in weight with bridges, buildings, etc. They are frequently in inaccessible locations where it may be difficult to haul the material and procure the proper kind of workmen. The fact must also be borne in mind that the overturning moment is great and that the sides of the towers should be as far apart as possible in the direction of the line, in order that the back foundation, which is in uplift, can be as small as possible. A successful type has been built with a bracing system in the longitudinal planes of the structure, as shown in Fig. 4. In order to keep the weight and size of the web

members down to a reasonable figure, it was necessary that the sides be not too far apart, as the necessary arbitrary specification to keep these members stiff must be kept in mind. This specification is based on the ratio of the unsupported length of the member acting as a column, to the radius of gyration of the member, and this should not exceed in main members, such as legs of the structures, 125, and in the minor members, 150 or 175, the latter being only unimportant members. This type of structure, also, requires considerable field riveting, which must be done with highly paid mechanics and entails a great deal of expense, especially where the structures are erected and riveted in position.

FIG. 6—TRANSMISSION LINE STRUCTURE GIVING CONSIDERABLE SPACING BETWEEN FOUNDATIONS
Pin-connected at the top.

Another type of structure is shown in Fig. 6. This can be pin-connected at the bases and at the top, and the construction is such that the ratios of length to radius of gyration in all the members can be kept within safe limits. The spacing between foundations in the direction of the line can be made considerable, thus cutting down the amount of concrete required in the foundation in uplift. This type of tower, of course, is not suitable for all conditions, but for a structure from 50 to 80 feet in height, it has been found to be economical in a number of cases. It is, of course, easily handled and erected in the field.

The practice in steel transmission structures in Europe has followed quite different lines from those in this country. Instead of

adopting the wind-mill type of tower, European engineers have largely made use of structures which were designed to stand the wind strains at right angles to the line, but to be somewhat flexible in the direction of the line in case of strains imposed by broken wires. Strains caused by wind cannot, of course, be relieved by bending of the structure, but strains caused by broken wires can be relieved by bending, as the movement of the structures will allow the wires to sag, thus lessening the strains.

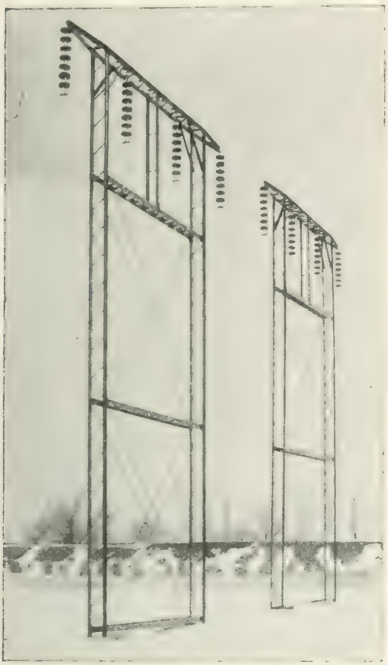


FIG. 7—STRUCTURES FOR CARRYING 200 000-VOLT LINES, EMPLOYING SUSPENSION TYPE INSULATORS

Experiments on such types of structures have been carried on by the writer's company and with the result that it has been decided that they are the most desirable type. Fig. 7 shows a pair of structures recently erected for a 200 000 volt line making use of suspended type insulators. These structures can be arranged for both pin and suspended type insulators for different voltages. Both built sections and rolled sections can be used as required for the members. These structures with the design calculated up to good structural specifications can be built at a reasonable cost. The field work is, of course, extremely simple and easily managed, which is a great advantage.

WALTER M. McFARLAND

WALTER M. McFARLAND

MR. McFARLAND has been connected with the Westinghouse Electric & Manufacturing Company, with headquarters at East Pittsburg, from January 1, 1899, until March 31, 1910, and has served as acting vice-president for ten years. He has resigned to take an official position with the Babcock & Wilcox Company and will be located at their general offices in the Singer Building in New York City.

His duties in the Electric Company brought him into intimate contact with probably a wider range of persons than any other officer of the company. He had direct personal relations with almost every department, being in direct charge of certain departments, and coming into official relations with other departments in the absence of other executive officers. He has received as the official host of the company, visitors and guests both from this country and abroad, and has won a wide reputation as a felicitous toastmaster. He has been a frequent representative at the meetings of engineering and other societies and conventions. Moreover, the period of something over eleven years during which he has occupied his present position is, in these days of rapid transition, a relatively long one. Thus it is that Mr. McFarland has come into personal and official relation with an exceptionally large number of men during his long term of office.

He has been the executive of the Electric Company having final visé of all large and important contracts. In connection with this work, he has greatly simplified and strengthened the standard forms of contract. He has had direct charge of the publication department of the company and under him this department has been built up into a compact and efficient organization, covering a wide range of activity. He has had a great deal to do with the settlement of delicate and intricate controversies where thorough and sound engineering sense, combined with the most kindly diplomacy, was needed.

Mr. McFarland has had an especial interest in the progress of young men and has had a considerable connection with the welfare work conducted by the company. He has been ever ready with counsel and encouragement for all those who have come to him in difficulty or perplexity.

Those who know him, and especially those who know him well,

appreciate particularly the personal qualities which have made their relation with Mr. McFarland most pleasant and that have made them feel that he is, first of all, their friend. It is, in fact, his genial, agreeable manner and his pleasing and attractive personality based upon underlying sincerity which have bound his friends to him and have made them feel that he is ready with sympathy and personal interest as well as official guidance.

Mr. McFarland's personal acquaintance with foreign countries, with public men and public affairs, has made him a veritable encyclopedia of information.

It is a great loss to any organization to part with the services of one who has been so prominently and widely identified with its work for so long a period, and it is a personal loss to those who have been in more intimate contact with such a man and have come to depend and rely upon him.

The following is an account of his early experience, condensed from a biographical sketch in *Cassier's Magazine* for May, 1901, by George W. Melville, then engineer-in-chief and rear admiral U. S. Navy:—

Walter Martin McFarland was born in Washington, D. C., in 1859. He is of Scotch-Irish descent, and shows the able and virile qualities of that race. His early education was received in the public schools of Washington, from which he passed to the preparatory department of Columbia University, winning the Kendall Scholarship of 1874 by competitive examination. In 1875 he entered the United States Naval Academy as cadet-engineer, and was graduated in 1879 second in his class. His sea service comprises duty on the North Atlantic and Europeans stations, 1879-81; on the U. S. S. Michigan on the Lakes, 1882-83; on the Pacific station, 1886-88; and again, on the European station, 1894-96. He was commissioned as assistant engineer in 1881; as passed assistant engineer in 1891; and as chief engineer in 1898, being then the youngest officer for more than twenty years to reach that grade and receiving the highest examination mark ever given in promotion to the latter. In 1899, after the passage of the Personnel Bill, he was commissioned a lieutenant; but in that year resigned to enter the employ of the Westinghouse Electric & Manufacturing Company.

McFarland's shore duty while in the Navy was as varied as his ability is versatile and his energy is untiring. His first service at the Bureau of Steam Engineering was in 1882. From 1883 to 1885 he was detailed from the Navy as assistant professor of mechanical

engineering at Cornell University, Ithaca, N. Y. On the completion of his term, the Hon. Andrew D. White, then the distinguished president of the university, requested an extension of his services, but the requirement of sea duty forbade. The years 1885-86 were occupied with the inspection of machinery then building and with work on preliminary designs for proposed vessels. From 1889 to 1894 he was again attached to the bureau, serving during the greater part of that period practically as the private secretary and confidential assistant of the engineer-in-chief. During the years 1897-98 these duties were resumed after a cruise at sea.

It will be seen that McFarland's Naval career covered a period of twenty-four years, divided about equally in service ashore and afloat. His knowledge and abilities were not limited to marine engineering *per se*. It is perhaps a truism to say that the acquaintance with pure and applied science which is possessed by the able practitioner in any branch of engineering equips him for service in many and varied fields of intellectual endeavor. So it was with McFarland. Indeed, I have never had an assistant who, while having a complete understanding of the duties of his own bureau, was better acquainted with the general work and scope of every section of the Naval Department and of allied branches of engineering which pertained thereto.

There are few officers who escape "Board" duty, and McFarland had a sort of life-membership on them. He was sent constantly to the various navy yards, shipbuilding and steel works to provide for the adjustment of engineering matters uncertain or in dispute; and his tact, sound judgment and quick decision were of the utmost service. Besides his routine and such extraordinary duties as the above, he acted as secretary-treasurer of the American Society of Naval Engineers and as editor of its Journal during the years 1890, 1892-93 and 1897. The laying out of the form and policy of this Journal and its subsequent success were due largely to him. For such work he was thoroughly equipped through his ability as a writer and the wide knowledge acquired by steady reading of current technical literature.

McFarland was the lecturer on marine engineering at the Naval War College at Newport, R. I., during the session of 1894. His lectures were republished in full in several technical journals. He was also the delegate representing the United States Navy Department at the International Congress of Naval Architects and Marine Engineers, at London, England, in July, 1897. During the World's

Fair, held at Chicago, in August, 1893, I had the honor of serving as chairman of the Division of Marine and Naval Engineering and Naval Architecture. In the work of organization, during the sessions, and in the publication of the proceedings, McFarland, as official secretary of this division, was one of the most potent factors in its marked success.

In November, 1897, the Secretary of the Navy assembled the "Personnel Board," with Theodore Roosevelt, then Assistant Secretary of the Navy, as its presiding officer. The duties of this board were to consider and advise upon the reorganization on modern lines of the Naval personnel. Its membership comprised some of the most distinguished officers of the line and engineers and, among them, McFarland had the honor of acting as the sole sponsor for the younger men of his corps.

The main result of the deliberations of this board was the recommendation for the adoption of the so-called "amalgamation scheme," i. e., the union of the former line and former engineer officers in a single combatant corps of what Colonel Roosevelt aptly termed "fighting engineers." In the development of an engineering Navy in an age of engineering, the amalgamation idea was wholly sound; for, aside from the necessity of giving the modern naval engineer military rank and title and military command of his men, it was, further, but a natural step to extend the engineering work of the modern line officer in steel inspection, ordnance, the care of electric auxiliaries, etc., to include as well the motive machinery, the very "vitals" of the ship he handled and fought.

From the first, McFarland was one of the most active and efficient supporters of the amalgamation plan. As a member of the board, he had the especial confidence of its president, Colonel Roosevelt; and he proved a powerful advocate of the measure before the Congressional committees, drawing from them the comment that he was the best posted man they had ever examined.

McFarland, as a worker, is of essentially a healthy type, buoyant, vigorous and inspiring. He has in marked degree a faculty which is essential to men of affairs, the power to preserve continuity of thought on any subject under frequent interruption and deflection. While quick in decision and action, his judgment is exceptionally well balanced and unerring. In closing this brief record, I can only say that I have written it with keen pleasure in my pride in and warm regard for one of the ablest and most winning men with whom it has been my fortune to be associated.

CONCRETE CONSTRUCTION OF SWITCH GEAR COMPARTMENTS IN EUROPEAN POWER PLANTS

STEPHEN Q. HAYES

IN Europe, as in America, the early electrical power plants containing a few machines of small output and moderate voltage, were readily controlled by simple, inexpensive, exposed switches mounted on the station walls or on a switchboard. As voltage and output increased it became necessary to utilize more space for the switch gear than could be found on the station walls, or on a switchboard proper, and to take more precautions to safeguard the attendants and to localize the trouble that might occur, due to defects in the switching apparatus.

Distant mechanical control for switch gear was adopted in Europe at an early date, and as a matter of precaution, the switch gear, bus-bars and connections were generally enclosed in cabinets or located in masonry structures or otherwise placed out of reach. The equipment was usually so arranged as to be accessible to the proper parties in case of necessity, but under ordinary conditions was inaccessible to the casual visitor or the unauthorized attendant.

As the voltage and amount of power to be handled in the stations increased, various switching devices were developed to handle circuits of large power and high voltage, but the oil switch and oil circuit breaker have practically superseded all other types of switch gear for alternating-current service.

Since the essential feature of the oil switch or circuit breaker is the opening of the circuit under oil and the smothering of the arc in a rather restricted space, it was soon found that explosions in the oil switch would occasionally occur when circuits of large power were being opened under load. The amount of power that could safely be handled by an oil circuit breaker depended on the strength of its tanks, the amount of the oil, the arrangement of the breaking contacts and similar features of design; but even with the most careful design, oil would frequently be blown out of the circuit breaker and occasionally its tanks destroyed. For this reason it has been found advisable in many instances to locate the oil circuit breaker and some of the other apparatus in a compartment, usually of concrete, so that even if the oil is thrown out of the circuit

breaker or the circuit breaker itself destroyed by an explosion, little additional harm will occur.

In Europe it is customary in all plants, except those of very large power or extremely high voltage, to use circuit breakers having all three sets of contacts for a three-phase circuit in one tank, and most of the European structures have been designed with this point in view. In some cases, however, the circuit breakers, particularly for high voltage, are arranged with each pole in a separate compartment. The bus-bars and connections are almost invariably arranged so that each phase occupies a separate compartment. Concrete has been used almost exclusively as a material for these compartments and by the use of excellent material and high grade workmanship, very elaborate and intricate forms have been made in concrete construction, horizontal shelves as well as vertical septums and barriers being made of this material.

It is, of course, impracticable to attempt to show and describe all of the various forms which these concrete switch compartments take in European construction. This article confines itself to a few examples collected from plants that have been installed in France, Switzerland, Italy and Spain by the "Societe Anonyme Westinghouse," the "Maschinenfabrik Alioth," the "Brown Boveri Company" and the "Maschinenfabrik Oerlikon." It might be stated, however, that the concrete construction as installed by these firms does not differ materially from that employed by other European manufacturers.

As the apparatus contained in the switch gear compartment is doubtless more interesting to the average reader than the compartment itself, the various features of construction are considered more particularly from the viewpoint of the apparatus than that of its setting. Furthermore, as the methods of construction, preparation of molds, mixing of concrete, etc., are fairly familiar to every engineer interested in concrete work, the results obtained in Europe rather than the steps in securing these results are outlined, illustrations of various concrete structures and short descriptions and explanations relative thereto, being given in connection with the following plants:*

Castel Nuovo Valdarno, Italy

(*Maschinenfabrik Oerlikon*)

The Castel Nuovo Valdarno system in the province of Tuscany

*See also article by Mr. Hayes on "Die Kraftwerke Brusio," a description of an interesting Italian power plant, in the Journal for February, '09, p. 69.

in Italy has a steam station located near the mouth of a coal mine in order to utilize a very poor grade of lignite coal. Babcock and Wilcox boilers are used, supplying steam to three horizontal engines of 2 400 hp capacity each, made by Franco Tosi at Legnano. These engines are direct-connected to 1 500 kw, 1 800 k.v.a, 6 000 volt, three-phase, 50 cycle generators built by the British Westinghouse Company, which supply power, through transformers and a 33 000 volt circuit, to Florence, Prato, Figline, Sienna and Valdarno.

The concrete compartment for the switch gear used for the control of one of the 1 500 kw generators is shown in Fig. 1. This compartment contains a voltmeter transformer, two shunt trans-

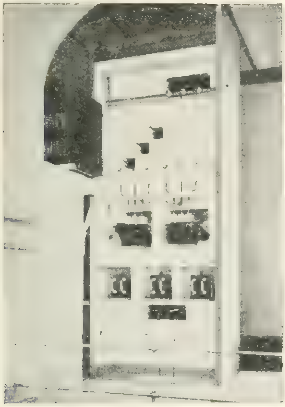


FIG. 1—CONCRETE SWITCH COMPARTMENT

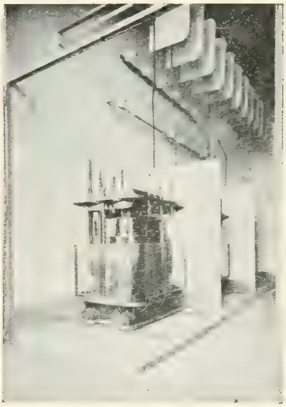


FIG. 2—600 K. V. A. AIR-BLAST TRANSFORMER COMPARTMENT

Castel Nuovo plant.

formers for the reverse current relays and wattmeter and two oil circuit breakers for connecting the generator to the bus-bars or to the step-up transformers. The other side of this compartment contains the over-load coils of the circuit breaker, one series transformer for the ammeter, two for the reverse current relays, and two for the wattmeters. The generator instruments are mounted on a pedestal which carries the levers for operating the various circuit breakers. The concrete structure containing this apparatus is noticeable for its smooth finish, sharp corners and workmanlike appearance.

One of the groups of three 600 k.v.a. step-up transformers is shown in Fig. 2. These are core type, air blast transformers and

like many European designs, have no casings or covers over the coils. The low-tension primary winding is next to the core with impregnated paper and mica cylinders between it and the high-tension winding, which is divided into twenty-six coils in order that the pressure between coils shall not exceed 600 to 800 volts. The transformers are mounted on wheels and can be pushed on to a little truck that runs in front of the compartments. These transformers are separated by concrete barriers and are mounted over an air blast tunnel. It may be noted that the concrete barriers between the transformers are not braced at the top, although the walls are

FIG. 3—33 000-VOLT AUTOMATIC OIL CIRCUIT BREAKERS IN CONCRETE COMPARTMENTS. OTHER CONCRETE CELLS AND BARRIERS FOR HIGH-TENSION APPARATUS SHOWN AT THE LEFT

Castel Nuovo plant.

comparatively thin. The concrete barriers between the disconnecting switches above the transformers are also noticeable. A feature of interest in connection with the transformer is the glass chimney placed around the transformer to assist in securing the proper distribution of air from the air blast chamber.

A view of the concrete compartment containing the automatic 33 000 volt oil circuit breakers and the connection to the bus-bars is shown in Fig. 3. Two-pole differential relays are used with these circuit breakers and three oil immersed series transformers supply current for ammeters and relays. These breakers are operated by

means of cables actuated from levers placed on a panel switchboard, and their operating mechanism closely resembles in design and general appearance a corresponding type of solenoid operated breaker built by the Westinghouse Company. This type of circuit breaker is arranged with two breaks per pole, each break occurring in a separate porcelain pot. The connections of the incoming and outgoing leads are made at the lower end of the pot, while the plunger rods enter the top and are connected to cross-arms operated from the mechanism on the upper framework. As may be noted, each pair of pots is located in a separate compartment with concrete walls between the pots. The concrete work of this structure is

FIG. 4—CONCRETE COMPARTMENTS; SOLENOID-OPERATED LINE CIRCUIT BREAKERS
Castel Nuovo plant.

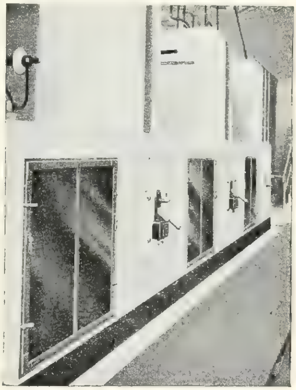


FIG. 5—SWITCH COMPARTMENTS AND HIGH-TENSION APPARATUS; 20 000 VOLTS
Clermont Ferrand substation.

remarkably well done and the shelves, barriers, openings and supports are as sharp and clean-cut as though soap-stone or marble had been used in place of concrete.

The line circuit breakers of this same plant are contained in a compartment shown in Fig. 4. They are solenoid operated and their mechanism corresponds rather closely to that of the Westinghouse type referred to in connection with Fig. 3, while the bottom connected tanks with operating rods resemble a corresponding General Electric type, except that the tanks are porcelain instead of metal or wood. The necessity for careful work on the concrete structure for such a breaker is self-evident, owing to the necessity of securing proper alignment between the tanks, mechanism and plunger rods.

This plant contains many other excellent examples of concrete construction, but the foregoing illustrations will suffice to show the main features of design.

Clermont Ferrand, France

(Societe Anonyme Westinghouse)

This plant, installed by the Societe Anonyme Westinghouse in 1904, is used for the transmission of power from a hydraulic plant to a distributing sub-station at Clermont Ferrand. The generating

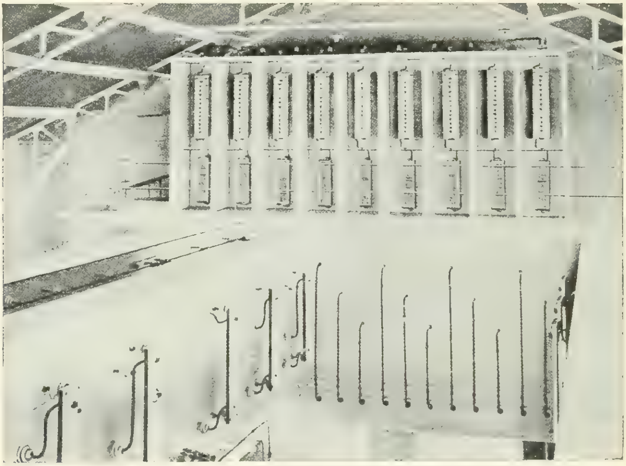


FIG. 6—CONCRETE CONSTRUCTION SHOWING LIGHTNING ARRESTERS IN COMPARTMENTS, RING BUS-BARS AND FUSE TYPE CIRCUIT BREAKERS

Clermont Ferrand sub-station.

station contains three 1 000 k.v.a., 1 000 volt generators, with provision for three additional generators, and step-up transformers for furnishing current at 20 000 volts to the transmission lines.

The arrangement of the apparatus for taking care of the three 20 000 volt incoming line circuits at the sub-station is shown in Fig. 5. Each incoming line is provided with three low equivalent lightning arresters, each with its own disconnecting switch, three single-throw knife switches, three open spiral choke coils, one three-pole oil circuit breaker and three single-pole, double-throw knife switches, so arranged that the incoming lines may be connected to either of two sets of ring bus-bars. As may be noted, the operating handle for the distant control oil circuit breakers are placed on marble slabs,

which are in turn bolted directly to a concrete wall, and concrete barriers are supplied for separating the various circuits. The sharpness of the concrete work is apparent in the illustration.

The low equivalent lightning arresters in this sub-station with their series resistances are shown in Fig. 6. The ring bus-bars are also to be seen at the left with the bases of the fuse type circuit breakers that are used for the protection of the individual banks of transformers. These fused circuit breakers, as may be noted, are located directly on the concrete wall, supported of course on insulators, on the floor above the transformer. The comparatively small size of the insulator bushings intended for the 20 000 volt transformer

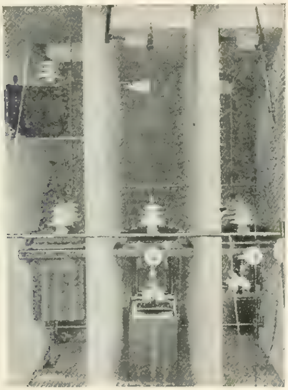


FIG. 7—AUTOMATIC OIL SWITCHES ON 40 000-VOLT CIRCUIT; SEVERAL BREAKS IN SERIES

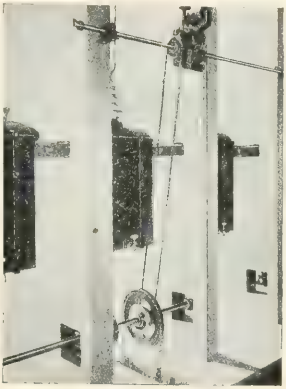


FIG. 8—CHAIN DRIVE OPERATING MECHANISM FOR SWITCHES SHOWN IN FIG. 7

Gromo-Nembro plant.

circuit is evident proof of the good quality of the porcelain and of the concrete construction used in this plant.

Gromo-Nembro, Italy

(Brown-Boveri Company)

The Gromo-Nembro power station, which is located in the northern part of Italy, was equipped by Brown-Boveri Company. The generating station is provided with three 4 000 volt, 50 cycle generators rated at 1 000 hp at 80 percent power-factor, each connecting to its own three-phase, 750 k.v.a. transformer stepped up from 4 000 volts to 40 000 volts.

A front view of the structure containing the 40 000 volt automatic oil switches is shown in Fig. 7. These switches are arranged

with each pole in a separate masonry compartment. The pole shown on the left is part of a three-pole switch for the transmission line, while the two poles in the center and on the right, respectively, are part of the three-pole switch on the high-tension side of the step-up transformers. In the left hand compartment the pole of the breaker is shown with its tank on. The central pole is shown with the tank dropped to the floor, while the right hand pole is shown with the tank completely removed. On a bracket above the circuit breaker is a series transformer of the oil immersed type. In the central and right hand compartments, the knife type disconnecting switches for isolating the circuit breaker appear above the oil breakers, while the operating pole with its grounding chain is seen near the right hand compartment.

The arrangement of the chain drive operating mechanism for these breakers is shown in Fig. 8. The oil switches are operated from a distance by means of hand wheels placed on the main switchboard and they are actuated by a rotating motion. It may be of interest to state that the 40 000 volt oil circuit breakers in this installation break the circuit simultaneously in six places. Although the travel of the moving contact is only eight centimeters, the total effective oil break is 35 centimeters, after allowing for the overlapping of the contacts which are provided with auxiliary contacts to take the final break, these auxiliary contacts being readily renewable. As may be noted, a common release spindle is provided for actuating the tripping mechanism of the individual poles of the circuit breakers, the movement of the spindle being due to the falling of a weight that is controlled in turn by a solenoid. There are various other interesting features in connection with these switches that cannot, however, be touched on in this article.

Gaucin-Seville, Spain

(*Maschinenfabrik Oerlikon*)

The Gaucin-Seville (Spain) power system, when originally installed by the Oerlikon Company, in 1906, to transmit power a distance of 125 kilometers at 52 000 volts, was the highest potential transmission plant actually in service in Europe. Power was secured from a fall in the river Guadiaro near Gaucin in the province of Malaga, and the power was transmitted to Seville, as well as to other intermediate stations.

The generating station contained three 1 300 k.v.a., 5 000 volt, three-phase, 40 cycle generators with two banks each of three 600 k.v.a. transformers having a ratio of 5 000 to 30 000 volts, these transformers being connected in delta-star for operation on a 5 200 volt circuit.

The 52 000 volt bus-bars in the generating station and the arrangement of the horizontal barriers, bus-bars, bus-bar supports, etc., are shown in Fig. 9. The fourth bus-bar in the lowest compartment is the neutral connection of the various transformers, this neutral point being connected to ground. It would be almost impossible to find in American practice horizontal concrete barriers of this size without pilasters or some similar means of supporting the outer edges of these shelves. The pillar type insulators used for

FIG. 9—52 000-VOLT BUS-BARS AND HORIZONTAL CONCRETE BARRIERS
Gaucin generating station.

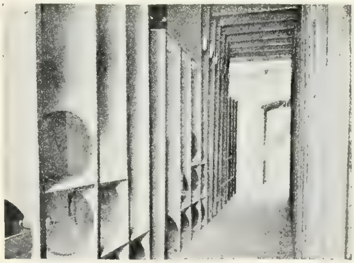


FIG. 10—50 000-VOLT BUS-BARS AND HIGH-TENSION CONCRETE COMPARTMENTS
Seville sub-station.

the support of the bus-bars and wiring are also typical of European construction.

The arrangement of the 50 000 volt bus-bars in the Seville substation is shown in Fig. 10. The horizontal and vertical barriers of concrete are clearly shown, also the clean-cut, circular openings in the walls and the bus-bar supports and bus-bar disconnecting switches.

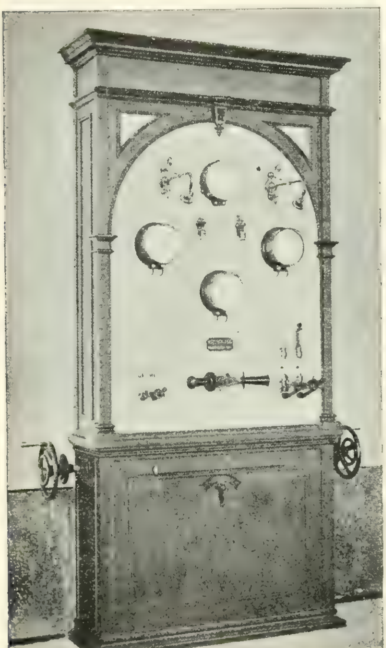
Haute Rive, Switzerland

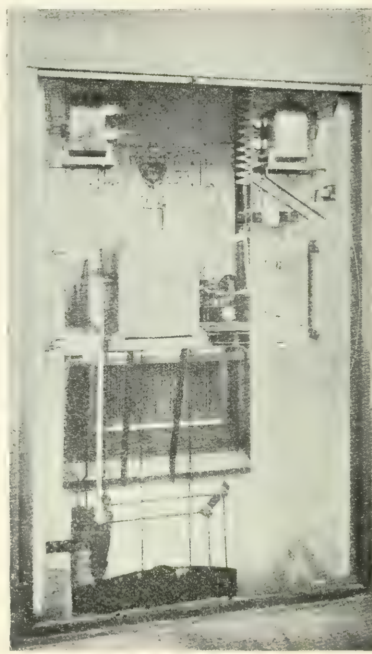
(Maschinenfabrik Alioth)

The generating station at Haute Rive furnished by the Maschinenfabrik Alioth is used for light and power service in the Canton of Fribourg in Switzerland, and also supplies power in emergency to the Montreaux Oberland Bernois Railway, running from Montreaux nearly to Interlaken, through the mountains of

Switzerland. This station is arranged to contain ten vertical shaft 8 600 volt, 50 cycle generators, each of 950 k.v.a. capacity, and each of these generators is provided with a control cabinet of the type shown in Fig. 11, these cabinets being placed along the wall of the station. Each pedestal is provided with a field ammeter and a main ammeter operated by series transformer, a main voltmeter, a synchronizing lamp, main circuit breaker, field switch, field rheostat and similar devices.

The rear view of one of these cabinets is shown in Fig. 12. It





FIGS. 11 AND 12—FRONT AND REAR VIEWS OF GENERATOR SWITCH CABINET
Haute Rive plant.

may be noted that this cabinet projects into an adjacent room and is normally enclosed by means of a rolling iron door. The general arrangement of the oil circuit breaker, instrument transformer, wiring, etc., is clearly shown. Cabinets of this same design are used by the Alioth Company at the Mont Boven station of the Montreaux Oberland Bernois Railway, at the Campo Cologno generating station of the Brusio transmission system, and in various other power plants throughout France, Switzerland and Italy.

Verzasca, Italy

(*Brown-Boveri Company*)

The Verzasca electric power system, installed by the Brown Boveri Company near the city of Lugano in Italy comprises a hydroelectric generating station at Gordola and a transformer station at Massagno. The generating station contains four main turbines built by Bell & Company of Kriens, each of 1 000 hp and operating at 500 r.p.m. under a head of 260 meters, as well as two 125 hp exciter turbines, running at 1 000 r.p.m. The generators, rated at

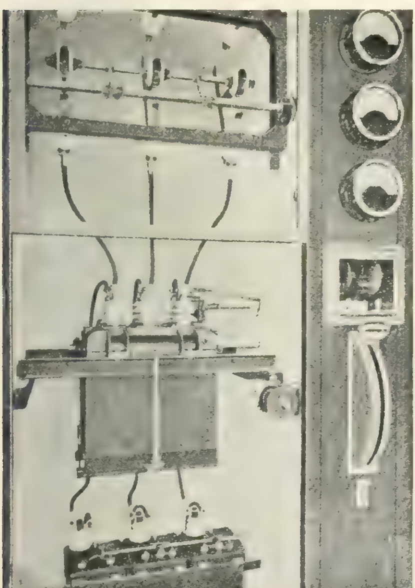


FIG. 13—3 600-VOLT THREE-POLE OIL CIRCUIT BREAKER IN CONCRETE COMPARTMENT

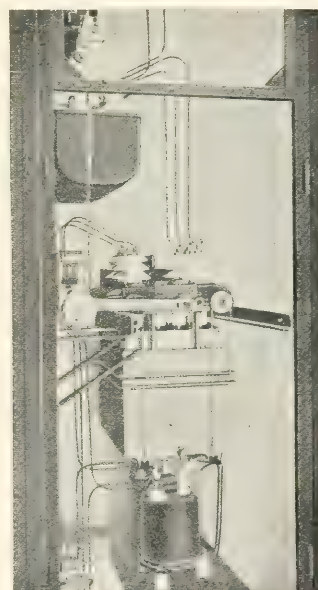


FIG. 14—24 000-VOLT THREE-POLE OIL CIRCUIT BREAKER SHOWING OPERATING MECHANISM

Massagno sub-station, Verzasca system.

920 k.v.a. capacity at 75 percent power-factor, 4 200 volts, 50 cycles, supply power to 850 k.v.a., three-phase, oil-insulated, water-cooled transformers which serve to step up the voltage to 25 000 volts for transmission to the Massagno receiving station, where it is stepped down by three-phase transformers to 3 600 volts.

The compartment in the Massagno sub-station containing the 3 600 volt transformer switch gear is shown in Fig. 13. A three-

pole mechanically operated knife switch is shown in the upper left hand portion of the illustration and serves when required to isolate the switch and other apparatus from the overhead bus-bars. The three blades of this switch are attached to insulators mounted on a shaft which is operated by chain drive from a shaft in the compartment to the left, which in turn is driven by the bevel gear apparatus to the right of the oil circuit breaker. The shaft of the bevel gear device has a square end and projects through the sheet metal door that ordinarily encloses all of the switch gear. Before the door can be opened this shaft must be turned by a socket wrench in such a manner as to operate this disconnecting switch and isolate the apparatus from the bus-bars. This is typical of the precautions taken to safeguard the attendants in European plants.

FIG. 15—TRANSFORMER KIOSQUE AT LUGANO
Verzasca system.

The oil circuit breaker is operated by a rotary motion obtained from a shaft projecting through the right hand wall and driven by a chain actuated by the handle projecting through the large sector to the right. The smaller handle below actuates the tripping device of the circuit breaker. A device, shown more clearly in connection with the 24 000 volt circuit breaker, Fig. 14, is provided for lowering the oil tank to obtain access to the contacts. An oil gauge placed at the front of the tank, Fig. 13, serves to show the height and condition of the oil. Series transformers of the oil immersed type are located at the bottom of the compartment and supply current to the ammeters and overload relay on the adjacent section. The various transformer and feeder compartments for the 3 600 volt circuits form a practically continuous switchboard on the floor above the transformers and below the bus-bars. In the compartment containing the 24 000 volt switch gear of the incoming lines, Fig. 14, a disconnecting switch with porcelain mounting is provided, it being chain driven from a locking device, as in the case of the 3 600 volt switch, Fig. 13, in such a manner that the door cannot be opened if the switch is closed. There are two sets of series transformers of the oil immersed type, and a three-pole oil circuit breaker. The drain cock and the tank lowering device for the circuit are clearly indicated. The mechanical construction of these cabinets with their

steel framing and brackets and concrete walls is an example of the completeness with which such details are designed.

An exterior view of one of the concrete transformer houses or *kiosques* in the city of Lugano is shown in Fig. 15. These transformer stations are supplied with power from the 3 600 volt circuits from the Massagno Station and contain, as a rule, two six kw, three-phase transformers supplying current to a three-phase, four-wire system, with 120 volts between each outside line and neutral, the neutral being grounded. These concrete stations, while very ornamental and in strict keeping with their surroundings, are not unduly expensive. The inside dimensions are approximately nine feet, six

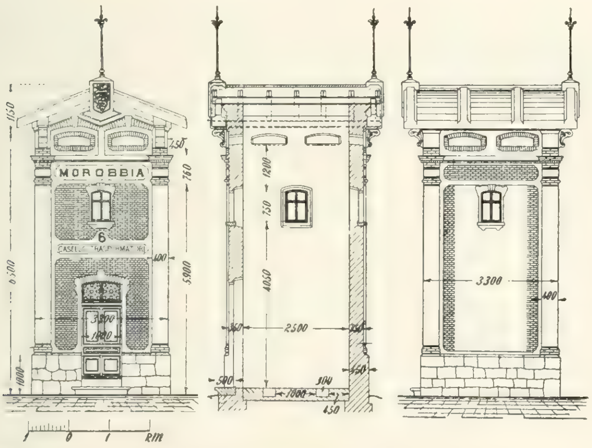


FIG. 16—THREE ELEVATIONS OF TRANSFORMER KIOSQUE AT BELLINZONA, ITALY

inches square, and they are divided into three floors. The ground floor, about nine feet, two inches high, contains one or two transformers; the second floor, ten feet, three inches high, contains the 3 600 volt, three-phase bus-bars and the high-tension transformer fuses, with porcelain holders. Similar fuses are provided in connection with the voltmeter on the secondary circuit, and there are also four or five three-pole knife switches for the main circuits, with single-pole switches in the neutral, and fuses for the protection of the low-tension feeder circuits. The top floor, 15 feet high, contains the lightning arresters, choke coils and switches for the 3 600 volt incoming lines, as well as the outlets for the 3 600 volt and 120 volt circuits.

Bellinzona, Italy

(Maschinenfabrik Alioth)

The general design of one of the twelve transformer houses supplied by the Alioth Company for the City of Bellinzona in Italy is shown in Fig. 16, this city being supplied by current from a hydro-electric plant on the Morobbia. The ornate appearance of these stations is evident from the illustration, but the fact that the same molds, etc., can be used for a large number of buildings greatly reduces the unit cost.

Montcherand-Compagnie Vaudoise, Switzerland

(Maschinenfabrik Oerlikon)

The Compagnie Vaudoise supplies power in the Canton of Vaud, Switzerland. The power plant at La Dernier contains five 1 000 hp turbines of the Pelton type made by Escher, Wyss & Co., and two of 150 hp, connected respectively to five 13 500 volt, 50 cycle, three-phase generators and two 800 ampere, 90 volt exciters made by the Oerlikon Company. A second station to contain four 2 000 hp units is being installed in Montcherand.

Power is distributed to various points in the Canton of Vaud at a pressure of 13 500 volts direct from the generators and is supplied to self-cooling transformers located in small reinforced concrete sub-stations. Reinforced concrete transformer and switching stations built by the Oerlikon Company, of a design similar to that shown in Fig. 16, are installed where the three-phase or single-phase lines branch off to various towns. These stations are provided with a basement and two upper stories, and are ten feet square, interior measurement, by 29 feet high. They are arranged to take care of one or two single-phase circuits and one three-phase circuit. As a rule the basement contains the air break plunger switches for the incoming lines, the second floor contains the switches for the outgoing lines and a one kw lighting transformer, while the top floor contains two series of horn lightning arresters with water resistances.

The transformer stations, of the same general construction as the switching stations, are of two classes, one containing only single-phase transformers and the other both single-phase and three-phase, there being a total of 171 of the former type and 52 of the latter. Their height is 23 feet, one type being six feet, eight inches square, and the other seven feet, three inches square, inside dimensions.

Owing to the standardizing of these transformer houses 196 were built in six months. These stations contain a basement and an upper floor with openings on each side for the primary and secondary wiring, closed by glass panes with one and five-eighth inch holes for the passage of the conductors. All of the switching apparatus is located on the main floor. One door gives access to the primary circuit breakers and the other to the secondary switchboard. On the second floor are located the transformers and the primary lightning arresters which are made of horn gaps with magnetic blowouts in series with water resistance. The transformers are all of the core type, the single-phase lighting units having a primary voltage of

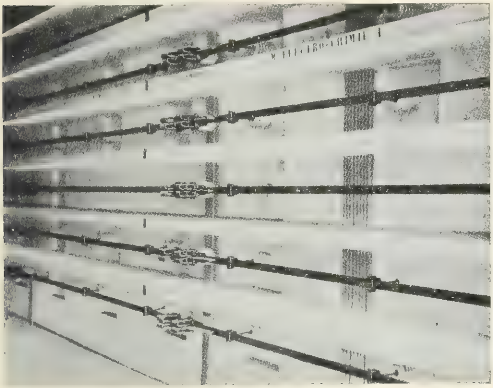


FIG. 17—13 500-VOLT RING BUS-BARS AND HORIZONTAL CONCRETE BARRIERS CONSTRUCTED WITHOUT PILASTERS. THE BUS-BAR SECTIONALIZING SWITCHES SHOWN IN THIS ILLUSTRATION ARE OF DISTINCTIVE EUROPEAN DESIGN

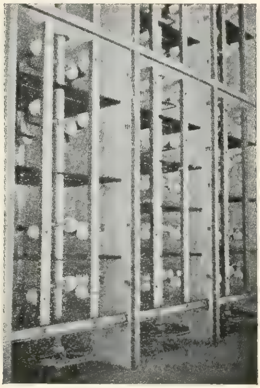


FIG. 18—THREE-POLE TRIPLE-THROW DISCONNECTING SWITCHES BETWEEN GENERATORS, FEEDERS AND BUS-BARS

Montcherand power station, Compagnie Vaudoise.

12 000 and a three-wire secondary of 125/250 volts, units of 10, 20 and 50 kw capacity being used. The three-phase transformers have a secondary voltage of 400 volts and are made in 20 and 50 kw sizes.

The second station of the Compagnie Vaudoise located at Montcherand contains four 2 000 hp turbines, made by Escher, Wyss & Co., which operate at a speed of 375 r.p.m. driving 13 500 volt, 50 cycle, three-phase generators made by the Oerlikon Company. The station is provided with three sets of ring bus-bars, shown in Fig. 17, to which the various generators and feeders are connected. The long unsupported concrete shelves are quite a departure from Amer-

ican practice and the type of bus-bar sectionalizing switch also differs considerably from that used in America.

Fig. 18 shows the type of three-pole, triple-throw disconnecting switch that is used for connecting the generator and feeder circuits to any of the three sets of bus-bars. These switches have blades supported on insulators attached to a vertical shaft and are operated by rope drive. The vertical and horizontal shelves of concrete with the structural iron framework and support makes a very satisfactory mechanical construction.

The two and three-pole 13 500 volt oil circuit breakers used in the various single-phase and three-phase feeder circuits supplied

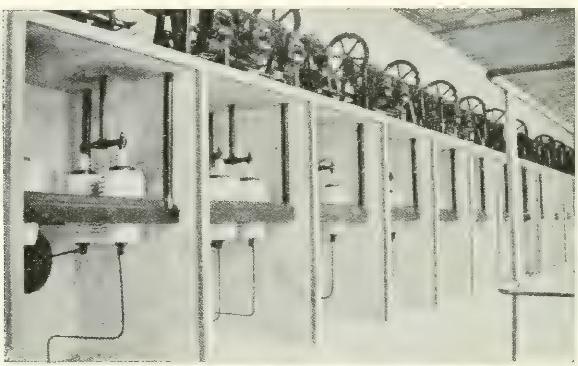


FIG. 19—13 500-VOLT AUTOMATIC OIL CIRCUIT BREAKERS SHOWING CONCRETE STRUCTURE AND ROPE OPERATED MECHANISM
Montcherand power station, Compagnie Vaudoise.

from this plant are shown in Fig. 19. These breakers are operated by rope transmission and are provided with overload relays for automatic trip. Each pole is provided with two porcelain pots containing oil. The connections of the incoming and outgoing leads are made at the bottom of the pots while the plunger rods enter the top and are attached to a cross-arm operated by means of the mechanism on the upper framework. The clean-cut nature of the concrete work is evident from the illustration.

Dell'Anza, Italy

(Brown-Boveri Company)

The hydro-electric power plant of Dell'Anza, equipped by the Brown-Boveri Company, comprises a generating station at Piedi-

mulera and receiving stations located at various points in the northern part of Italy. The generating station equipment comprises 2 750 hp main turbines direct-connected to 2 450 k.v.a., 8 000 volt, three-phase, 42 cycle generators, supplying power through 2 300 k.v.a., 8 000/45 000 volt, three-phase oil-insulated, water-cooled transformers to the transmission lines, and two 200 hp exciter turbines.

Two of the 45 000 volt, three-pole, automatic oil circuit breakers used in the plant are shown in Fig. 20. Each circuit breaker has its three poles in independent compartments and is provided with six breaks in series per pole. The three poles are actuated by a com-

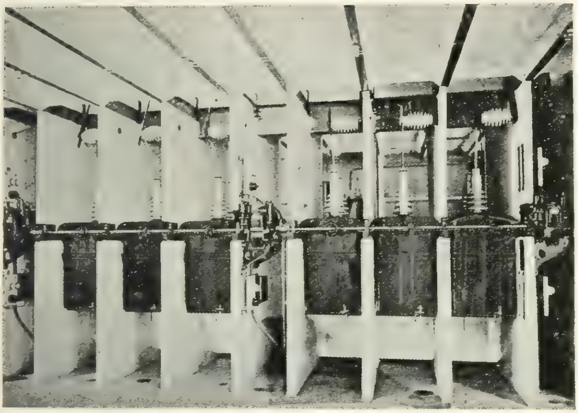


FIG. 20—TWO SETS OF 45 000-VOLT CIRCUIT BREAKERS IN CONCRETE COMPARTMENTS
Piedimulera power station, Dell'Anza system.

mon shaft driven by a motor with suitable clutch couplings and a spiral spring device. The concrete walls between the poles of the breakers are excellent examples of this kind of work. The porcelain bushings in the top of the circuit breaker tank and the porcelain studs of the swinging type disconnecting switches are typical of European practice.

Examples of concrete construction similar to the foregoing can be found in power plants in various parts of Europe, and, by a careful study of such work, the engineer can get valuable suggestions and excellent models to follow when contemplating concrete construction for switch gear compartments.

THE APPRENTICESHIP COURSE AND THE ENGINEERING GRADUATE

CHAS. F. SCOTT

THE question what he shall do after he graduates is uppermost in the mind of the senior student as commencement approaches. And well it may be, for the present decision may have a critical bearing upon the future career. The first few years largely determine what may follow. Hence the importance of a wise choice.

There are certain things which are needed to supplement a course in a college or technical school in order to fit and round out a man for his life work. The school does not give the whole preparation. While the suggestions which will be made are intended to have particular reference to the electrical graduate, they apply in a large measure to engineers in general. Later on the lines between the branches of engineering are not as distinct as they are in college. Electrical engineers are apt to find that much of their work is general engineering, and many others who are in positions of responsibility as mechanical, operating, consulting or railway engineers or as business men or managers of properties, find that electrical work forms quite an important part of the affairs with which they have to deal. This is likely to be the case to a greater extent in the future, as electricity is assuming a larger and larger place in modern affairs. Hence, a practical acquaintance with industrial electricity is a safe asset for all engineers.

The graduate who views the situation broadly should seek a place where he may add to his knowledge, supplementing the theoretical by the practical, as it is commonly expressed. He should be situated where he may gain useful experience, and he should aim to be where there are good opportunities for development and advancement.

The writer intends to point out how the desired knowledge, experience and opportunity may be secured in the apprenticeship course of an electric manufacturing company; many of the points are general in their nature, while some are more specific and are based upon his own acquaintanceship with the appren-

ticeship course of the Westinghouse Electric & Manufacturing Company.

KNOWLEDGE

1—*A Knowledge of Commercial Electrical Apparatus* — One should become familiar with the construction of commercial apparatus and the principles on which it is based; he should be familiar with its operation, both as to its mechanical characteristics and its electrical performance, and the field of its application and use. A definite knowledge of electrical apparatus and what it will do is the fundamental basis for all electrical work, whether it be designing, erecting, selling, consulting engineering or the general management or superintendence of electrical properties. In other lines, which are not strictly electrical, such a knowledge may be of great value. The engineer or superintendent or manager of a factory, a mine or a railroad is apt to depend upon electricity in some department of his work, and his success may depend very largely upon his own first-hand knowledge of dynamos, motors, transformers and controllers.

Now such a knowledge of commercial apparatus is not, and should not be, obtained in the technical school; that is the place to learn the principles and the general methods. The school has neither the time nor the facilities for familiarizing the students with the commercial apparatus; this knowledge should be acquired afterwards. And this practical knowledge can be gotten only by actually working with the apparatus.

The best place to learn how apparatus is made and how it works is in the factory where it is manufactured and tested. A large factory, moreover, gives a wide variety in sizes and types of apparatus. It gives opportunity for acquaintance with big things; laboratory apparatus is small and does not familiarize one with large machinery. The logical conclusion, therefore, is that the young electrical engineer and the young engineer in general should acquire a definite, concrete knowledge of how electrical apparatus is made and what it will do, for he will need this knowledge as a definite, concrete basis for future work which may be directly or indirectly related to electricity, and the best place to acquire this knowledge is in a large manufacturing company.

2—*A Knowledge of Manufacturing Processes* — Engineering and manufacturing are closely allied. The factory itself as well as its processes, its machinery and its products are the result of

engineering development; and engineering in nearly every branch uses the products of the factory. The general methods and processes of manufacturing on a large scale, and the physical and material elements which enter into a manufacturing plant are all typical of the modern method in industrial work. The function, arrangement and operation of tools, the facilities necessary for cheap production, the whole equipment, arrangement and operation of the modern factory should be familiar to the engineer.

An electric manufacturing company with its diversified product and its progressive up-to-date methods affords one of the best opportunities for observing and learning the machinery of production.

3—*A Knowledge of the Methods in a Large Organization*—The large corporation is the modern industrial method. Many manufacturing and industrial enterprises have, within the past generation, changed from a small business in which a single man was owner, manager and expert, to the large corporation where things are done on a large scale by the coöperation of many men. Such enterprises involve engineering work, and on the other hand there is comparatively little engineering which is not, in one way or another, connected with a large corporation of some kind.

In a large organization the administration must be divided and subdivided among many men and they must together do what one man does in a small business. When a single man designs and plans and executes, the whole scheme is automatically coördinated in one brain; but when magnitude requires that the one man be replaced by a dozen or a hundred, then the coördination among them which will bring a single and efficient result must be brought about through an efficient system. They are acting as parts of one whole, they must somehow do together on a large scale what one man can do alone on a small scale, and it is no easy matter to secure the same harmony and efficiency when many men perform different functions as are secured when they are performed by a single man. How men work together, the relations between different departments, the system necessary for tying together the many men who act as a single large unit, in short, the methods in modern large business, are matters of first consequence. Hence, it behooves the young man who looks forward to an engineering career, to come into intimate contact with a large company or corporation and with the modern methods of conducting manufacturing and industrial enterprises.

A large electric manufacturing company is an excellent field for such an experience. It embraces many departments—commercial, engineering and manufacturing, each of which is necessarily divided and sub-divided, and yet all are part of a single unit.

4—*Familiarity with Industrial Conditions*—Modern industrial life consists not merely in machinery and factories, processes and systems, but it includes the human element and brings together in a single organization and into a single community, men of all grades and types. To know these men, how they work and how they think, to understand the conditions which surround them and to understand their point of view, is an opportunity which the young engineer should not miss. The larger and more difficult industrial problems which will come up for solution during the next generation are not those of machinery but of men. It is this relation which underlies much of the industrial, social and political unrest of the present. The coming engineer will have more and more to do with the handling and direction of men and furthermore his education and training, his natural relationship to industrial affairs supplemented by a first-hand knowledge of conditions and of men, should make the engineering profession a useful instrument in working out the problems of modern life which are very largely the outcome of the new conditions which engineering itself has produced.

Hence, the graduate will do well to enter into life where he can observe and feel these new conditions. He can do so by becoming part of a large manufacturing company and preferably should be located in an industrial community, surrounded by other factories, where he may see modern industrial conditions at short range.

EXPERIENCE

1—*A New Point of View*—The common comment of men who employ college graduates is that they are not of much consequence for a year or two. They must undergo the experiences of real life until the college ideas and ideals have been radically changed. Now the graduate may not understand just what this means and he may be ready to argue that it is not so. He will do better, however, to assume that the older men may be right and to place himself where he may stand a good chance of getting the new point of view. One of the things to be learned is how to work. The student may work hard, but he works for

himself. The whole school is for him,—endowment, buildings, equipment, and professors—all exist in order that he may develop. He is the center of a little universe. It is hard to change the point of view, to change the object of effort from self to service. The graduate at first expects everything to minister to him, he expects his foreman to be his teacher, he wants to shift from one place to another as soon as he has learned a little and the newness is gone. But the real object in life is to work for others, it is the law of common labor, and to be a servant is the ideal of the Christian life. Many young men fail because they are too self-centered. They need to enter a great workshop and render a service which is larger than the pay envelope, for not until then are they profitable.

To come into vital contact with real life quickly, one had best get into the midst of the practical industrial world where activity is concentrated, where discipline is rigorous, where he may realize himself as an infinitesimal part of a great organization. The apprenticeship course gives one a new perspective of the conditions, and it has the approval of hundreds who look back to it and value its lessons, many of them hard lessons, in the school of experience.

2—*Contact with Men*—The student in school is surrounded by men of his own kind. As an engineering student he is apt to keep within the narrow confines of technical study, neglecting literary or debating societies, discarding the more liberal subjects of the broader courses, and avoiding rather than seeking intercourse with men of different views. After graduation he should come in contact with men of widely different types. He will find them in a large electric manufacturing company. Here he is side by side with workmen. He gets a new insight into labor. He learns that there is an ability which does not come from books and finds that his own commonsense and personality count for more than his diploma. He is among hundreds of picked men of his own kind, from dozens of colleges, ambitious, earnest and hopeful. Intercourse is stimulating and acquaintances are found which will be a valuable asset in professional and business life of later years. He is surrounded also by older college men who have found their work. He may see many examples of men who have come to positions of trust by the same road he is traveling, and he may profit by their counsel as well as their example. He is in an organization directed by men of

ability who have risen to the places they occupy because they are fitted for them. He may observe their qualities, their methods and their results. Now these relations with men of many kinds give the observant young man a needed breadth of experience in his formative years.

3—*Getting Along with People*—The inability to get along with other people smoothly and efficiently is the cause of more failures by engineering graduates, than lack of technical knowledge. Young men whose knowledge, training, ability and experience have well fitted them for advanced positions have not been able to succeed because they could not get along with the people with whom they were thrown in contact. Often this has resulted from a narrow, self-centered point of view and from failure to really understand the point of view and the methods of others. Sometimes it is from lack of tact and commonsense discretion. The engineer in almost any field of work in which he may enter, unless possibly it be using a slide rule in a quiet corner, must depend upon the assistance and coöperation of others. He should make it a point to place himself in his early years where he will of necessity come in contact with many people, and where he may see examples of coöperation on a large scale, and where he must himself depend for his progress and his success upon the cultivation of the art of getting along efficiently with other men. Also he should learn the true principle of organization in a democratic community. "Getting others to do what you want done, while they are doing what they themselves wish to do. Inspiring others to do what you want done; not driving them to do it; setting before them the object of their ambition and affections in the line of your own purposes."*

OPPORTUNITY

1—*To Find What One is Fitted For*—The graduate often does not know his own qualities, nor the various fields of work which lie open to him; nor is it necessary that he should. His prime purpose so far in life has been to fit himself, by acquiring knowledge and developing his ability to think and to work. If he has done this, if he has made himself capable, then it is a matter of small consequence just what kind of knowledge he may have acquired or what views he may have as to his own preferences. If he has

*From "Man-Power," by Mr. T. C. Frenyear, in the JOURNAL for March, 1904.

fairly definitely decided upon the particular work he wants to do, well and good. In most cases, however, the man needs to find himself in the new conditions of active life. He should place himself where he may test his own qualities and find out what kind of a man he really is. If he is surrounded by men of many kinds in different activities, if he is thrown among many who are substantially his equals, he has a chance to come to a fair estimate of himself.

A first-hand knowledge of the fields of work which are open to him will make it far more likely that his choice may be a wise one and that his life work will begin where his ability and his interest give the best promise of success. This is one of the advantages of an apprenticeship course over a position which may be more attractive in point of eminence or compensation, but in which the man is relatively isolated and does not have the opportunity of comparing himself with others.

2—*A Choice of Many Fields of Work*—Many openings have but a single outlet. The young man who has not yet tested himself in the crucible of real life, who does not really know what he is best fitted for, nor what kinds of work are open to him, had best enter where there are many outlets. Such are the conditions in the modern electric manufacturing company. First of all, its purpose in establishing an apprenticeship course is to secure men who will be trained for its own service. Its first interest is, therefore, to secure efficient men. Its own interests as well as the interests of the individual are served when each man is in that kind of work in which he can be most useful. An organization employing many thousands of men, and covering a wide range of activities from manufacturing to sales, has such a diversified need for men that it is difficult to give a concrete idea of the range of opportunities which are open. This is particularly true in the electrical business in which growth and changes are constantly required by the advance in the electrical field in which the activity doubles in periods of about five years.

The works department of a manufacturing concern has opportunities for college men which they have been slow to realize. The factory as a means of modern production has abundant need of technical and administrative ability. The modern factory needs foremen, superintendents, managers, and experts who have technical training as well as practical experience. The engineering department in an electrical company is necessarily an im-

portant one. Men are required for research, for original design and for the adaptation of ordinary types of apparatus to new and special conditions. Engineers must keep in close touch with the sales, manufacturing and testing departments. The erecting department, having to do with the installation of new apparatus in all parts of the country, is one of the best schools of experience, both as to machinery and as to men. The sales department utilizes men of many kinds. The engineer-salesman and the commercial engineer have come to the front in electric salesmanship. When this is the case, and the sales department is composed very largely of college men, and when those in charge of sales departments are men who are trained engineers, it is superfluous to argue that there are many opportunities for engineers in the sales department of an electric company. Not only do these and other departments in a large company need men but the apprenticeship course, particularly if it be followed by a few years in regular service, is an excellent preparation to fit men for positions with operating companies and for engineering work of all classes.

A review of the present positions of a large number of men who have taken an apprenticeship course shows that they are now widely scattered. Only one-third have remained with the company, the most of them being in the sales, engineering and erecting departments. Those who have gone elsewhere are engineers with railway, lighting or power companies, or are experts or consulting engineers, or are engaged in business closely related to electrical or engineering work.

A number are instructors and very few are in occupations where their training as engineers and in the apprenticeship course is not of direct value to them.

The writer recently had an opportunity of reviewing the letters from several hundred young men who had taken an engineering apprenticeship course and was impressed with the practical unanimity as to its value. Many pointed out matters which they had regarded as hardships at first, but which they had later come to regard as most valuable experiences. There were a few suggestions as to changes in the methods of conducting the course, but nearly all regretted that they had not worked harder, or had left the course before completing it, or had spent too large a proportion of the time in the office instead of in the factory.

RATINGS OF SINGLE-PHASE TRANSFORMERS FOR GROUPING ON POLYPHASE CIRCUITS

H. C. SOULE

It is the intention of this article to analyze the various groupings of single-phase transformers on polyphase circuits and to explain in a simple manner why certain groupings should have transformers of larger rated k.v.a. capacity than would be indicated if the capacity of each unit were determined by dividing the k.v.a. rating of the group by the number of transformers comprising the group.

As all single-phase transformers have a certain k.v.a. rating, based on the frequency, voltage and current ratings, any increase in voltage or current means an increase in the k.v.a. developed in the unit over its normal rating which results in extra heating. If the voltage is increased, the iron loss becomes greater. If the current is increased the copper loss has a higher value.

It is an increase in current above the normal rated current which makes it advisable, in some cases, to use transformers whose combined k.v.a. capacity is greater than the k.v.a. capacity of the group. In all cases where it occurs this increase is 15.5 percent, as will be shown.

Two-phase to two-phase transformation does not offer any chance for error, as the transformers can only be connected so that the rating of each transformer comprising the group is equal to one-half the group rating. In fact this system is practically the same as two single-phase transformers operating in parallel on a single-phase system, except that here the two transformers are connected in quadrature.

Three-phase to three-phase transformation can be obtained by various methods, the more common employing the delta or star connections. These two systems will be analyzed first, as they are the most simple and form explanatory steps to the other systems.

As stated above, every single-phase transformer has a voltage and current rating which will be designated as E and I, respectively. From this it is fundamental that with three transformers delta-connected, the line voltage and current will be E and 1.73 I respectively, while the k.v.a. in the line is equal to $1.73 I \times E \times 1.73 = 3$ E I. These line values of voltage, current and k.v.a. will

be assumed for all the cases discussed, and for convenience, a one to one ratio of transformation will also be assumed. But one winding is indicated in the figures, as the other is the same except for case (E), which is for three-phase to two-phase transformation.

(A)—Three transformers delta-connected (Fig. 1).

In this case the rating of each transformer is one-third of the group rating, or, expressed in detail, the k.v.a. rating of each transformer is equal to $3\,\frac{EI}{3}=EI$, since the transformer voltage equals the line voltage, E, the transformer current equals the line current, divided by $1.73 = I$ and the resultant k.v.a. developed in both the primary and secondary windings is therefore $E \times I = EI$.

(B)—Three transformers star-connected (Fig. 2).

Here again the rating of each transformer is one-third of the

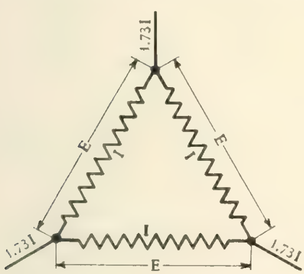


FIG. 1—DELTA CONNECTION

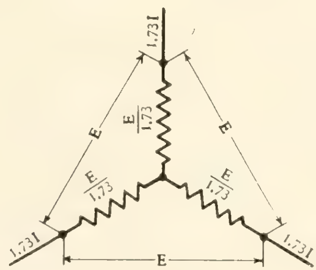


FIG. 2—STAR CONNECTION

group rating. That is, the k.v.a. rating of each transformer is equal to $3\,\frac{EI}{3}=EI$, since the transformer voltage equals the line voltage divided by $1.73 = \frac{E}{1.73}$, the transformer current equals the line current $= 1.73\,I$, and the resultant k.v.a. developed in both the primary and secondary windings is $\frac{E}{1.73} \times 1.73I = EI$.

If three transformers are connected in delta on one side and in star on the other, it is obvious that the values for the delta connected windings are the same as for (A), while the values for the star connected windings are the same as for (B), and therefore the k.v.a. rating of each transformer is equal to $3\,\frac{EI}{3}=EI$.

(C)—Two transformers V or open-delta connected (Fig. 3). In this case the rating of each transformer when in the group is

TABLE I—REQUIRED RATINGS

OF SINGLE-PHASE TRANSFORMERS FOR POLYPHASE TRANSFORMATION.

Connections Employed. Primary and Secondary.	Number of Trans-formers in Group	Values for Each Transformer of Group.			
		Winding.	Voltage.	Current.	K. v. a.
Delta to Delta	3	Primary, Secondary	E	$\frac{1.73I}{1.73}$	$\frac{W}{3}$
Star to Star	3	Primary, Secondary	$\frac{E}{1.73}$	1.73I	$\frac{W}{3}$
Delta to Star	3*	Primary	E	$\frac{1.73I}{1.73}$	$\frac{W}{3}$
		Secondary	$\frac{E}{1.73}$	1.73 I	$\frac{W}{3}$
V to V or Open Delta	2	Primary, Secondary	E	1.73 I	$\frac{W}{2}$ X 1.155
T to T	2†	"Main" Primary and Secondary	E	1.73 I	$\frac{W}{2}$ X 1.155
		"Teaser" Primary and Secondary	0.866E	1.73 I	$\frac{W}{2}$
Three-Phase to Two-Phase	2††	"Main" Primary	E	1.73 I	$\frac{W}{2}$ X 1.155
		"Main" Secondary	E	$\frac{1.73I}{1.155}$	$\frac{W}{2}$
		"Teaser" Primary	0.866E	1.73 I	$\frac{W}{2}$
		"Teaser" Secondary	E	$\frac{1.73I}{1.155}$	$\frac{W}{2}$

*For Star to Delta connections, reverse primary and secondary values.

†Customary to use duplicate transformers with 86.6% taps, each transformer having same rating as "Main" transformer.

††Customary to use especially designed transformers with 86.6% taps in three-phase winding and extra capacity in same winding.

58 percent of the group rating. The natural assumption that each transformer should have a k.v.a. rating equal to $\frac{3\ EI}{2} = 1.5$ EI is not correct, since the transformer voltage equals the line voltage = E, the transformer current equals the line current = 1.73 I and the resultant k.v.a. developed in both the primary and secondary windings is E × 1.73I = 1.73 EI, which is 15½ percent in excess of 1.5 EI. Therefore, for this connection, each transformer should have a k.v.a. rating equal to $\frac{3\ EI}{2} \times 15.5 = 1.73$ EI, which is approximately 58 percent of the group rating.

(D)—Two transformers T-connected for three-phase to three-phase transformation (Fig. 4).

With this connection also the rating of each transformer is 58 percent of the group rating. To analyze this it will be necessary to consider each transformer of the group separately. Referring to

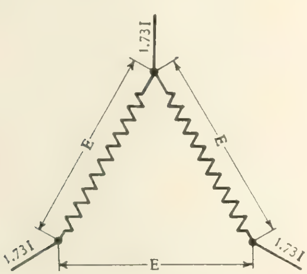


FIG. 3— V CONNECTION

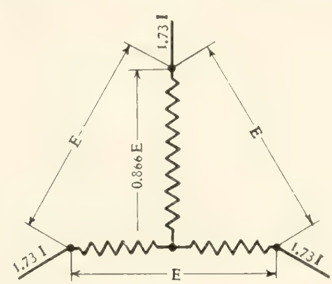


FIG. 4— T CONNECTION

the figure, the transformer whose voltage equals the line voltage is called the main transformer, while the transformer whose voltage equals 86.6 percent of line voltage is called the "teaser" transformer.

In the main transformer the transformer voltage equals the line voltage = E, the transformer current equals the line current = 1.73 I, and the resultant k.v.a. developed in both the primary and secondary windings is E × 1.73 I = 1.73 EI. It will be noted that this is 15.5 percent in excess of the rating the transfromer would have if its rating were taken as one-half the group rating or 1.5 EI. Therefore, the main transformer should have a k.v.a. rating equal to $\frac{3\ EI}{2} \times 1.155 = 1.73$ EI, or approximately 58 percent of the group rating.

In the teaser transformer the transformer voltage equals 86.6 percent of line voltage = 0.866 E, the transformer current equals

the line current=1.73 I and the resultant k.v.a. developed in both the primary and secondary windings is 0.866 E×1.73× I = 1.5 EI. As this is equal to one-half the group rating, the natural assumption is correct for this transformer. However, it is customary to use duplicate transformers for this system of grouping, the 0.866 voltage being obtained by means of a tap in the winding. Therefore each transformer should have a k.v.a. rating equal to approximately 58 percent of the group rating.

(E)—Two transformers T-connected for three-phase to two-phase transformation (Fig. 5).

From the figure it will be noted that the primary windings are connected the same as for the T connection explained under (D). As in that case, there is a main and a teaser transformer, but the primary (three-phase) windings only are affected since the secondary windings are connected the same as in two-phase to two-phase transformation.

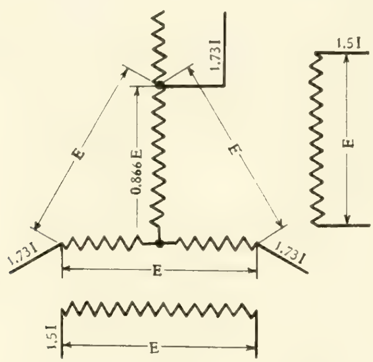


FIG. 5—THREE-PHASE—TWO-PHASE CONNECTION

The k.v.a. developed in the primary windings of the main transformer and teaser transformer, respectively, is the same as that developed in the same windings T-connected, or 1.73 EI and 1.5 EI, respectively. Therefore, the primary winding of the main transformer should have a rating 1.155 times one-half of the group rating and as duplicate transformers are used, the primary winding of the teaser transformer should have the same rating. It is customary to design transformers for this system of connection with extra capacity in the primary or three-phase winding only.

For two-phase, four-wire operation the secondary circuits are as shown herewith. For two-phase, three-wire operation, the right-

hand secondary terminal at the bottom of the diagram is connected to the lower secondary at the right of the diagram and the middle wire of the three-wire secondary circuit connected thereto. In either case the two-phase voltages bear a 90-degree relation to each other and the primary or three-phase voltage relations are not affected.

The foregoing may be summed up as follows, assuming in each case that the transformers are so selected as to give the same output for the three-phase group:—

(A)—Three single-phase transformers delta connected.
Individual unit k.v.a. rating equals one-third group rating.

(B)—Three single-phase transformers star connected.
Individual unit k.v.a. rating equals one-third group rating.

(C)—Two single-phase transformers V or open delta connected.

Indivdual unit k.v.a. rating equals one-half group rating multiplied by 1.155 or approximately 58 percent of the group rating.

(D)—Two single-phase transformers T-connected for three-phase to three-phase transformation.

Individual unit k.v.a. rating equals one-half group rating multiplied by 1.155 or approximately 58 percent of the group rating.

(E)—Two single-phase transformers connected for three-phase to two-phase transformation or vice versa.
Especially designed transformers should be used, each transformer having the winding to be connected three-phase designed for a k.v.a. rating equal to one-half the group rating multiplied by 1.155 or approximately 58 percent of the group rating. The secondary windings of each transformer should be designed for a rating equal to one-half the group rating.

OPERATION OF DELTA AND V-CONNECTED TRANSFORMERS IN PARALLEL

E. C. STONE

DELTA and V or "open-delta" transformer connections are both in common use. In an ordinary symmetrical delta or Y three-phase transformer grouping, the capacity of the group is the same as the aggregate capacity of the individual units. Sometimes delta and open delta groups of transformers are operated in parallel, in which case the capacity of the total group is less than the sum of the capacities of all of the individual transformers in the group. Thus, three 500 k.v.a. transformers, whether connected on a single-phase circuit or in a three-phase star or delta group, will have a capacity of 1 500 k.v.a. Two 500 k.v.a. transformers in a three-phase V group have an aggregate capacity of 866 k. v. a. However, when delta and V groups are operated in parallel the resultant capacity is not the sum of the delta and V ratings. The load is assumed to be equal on the three phases and the capacity of a group is reached when the transformer carrying the greatest load is operating at normal capacity.

The transformer capacities available with various combination of V and delta groups of units are given in Table I. This table brings out a number of notable points:—

For instance, more than one V group of two transformers cannot be used advantageously with a delta group of transformers nor with two or more paralleled delta groups. Three delta-connected transformers when added to another delta group will give an increase of capacity of 50 percent greater than four transformers connected in two V groups and added to the same delta group. This is because the four transformers, which would form two V groups, can be re-arranged to form a delta group (one transformer remaining idle), and the delta group will have the capacity of three transformers while the two V groups will add the capacity of only two transformers.

The addition of *two* transformers connected in V in parallel with a delta group adds the capacity of only *one* transformer to the capacity of the total group.

Although two V-connected groups should never be used in parallel with a delta group, they may be paralleled with one another and in this case will give a greater capacity than three units connected in delta. The capacity of the two V groups would be

TABLE I—TRANSFORMER CAPACITIES

AVAILABLE WITH VARIOUS COMBINATIONS OF V AND DELTA GROUPS.

Number of Transformers	Connection	Three-Phase Capacity of Group	
		In Percent of Single-Phase Rating	Equivalent Number of Single-Phase Units
2	V	86.6	1.75
3	▽	100	3
4	V V vs. ▽ / or V ▽	86.6 82	3.5 3.25
5	V ▽	80	4
6	▽ ▽ vs. V V V	100 86.6	6 5.25
7	▽ ▽ / or ▽ V ▽ vs. ▽ V V	91 72	6.5 5
8	▽ ▽ V	88	7
9	▽ ▽ ▽	100	9
10	▽ ▽ ▽ / or ▽ ▽ V ▽ vs. ▽ ▽ V V	94 80	9.5 8
11	▽ ▽ ▽ V	91	10
12	▽ ▽ ▽ ▽	100	12
13	▽ ▽ ▽ ▽ / or ▽ ▽ ▽ V / vs. ▽ ▽ ▽ V V	95 85	12.5 11

0.866 times four or 3.46 as against three, the corresponding rating of three transformers connected in delta.

When two parallel V groups are used alone they should always be connected as shown in Fig. 1 and not as in Fig. 2. The

connection shown in Fig. 1 amounts to putting two transformers in parallel on each side of a V, while Fig. 2 amounts to a delta connection with an extra transformer on one side of the delta. In the second case the available capacity is but 82.7 percent of the normal single-phase rating as compared with 86.6 percent for the first connection. When, however, four transformers are available to be added to one or more delta groups, an additional delta and an extra unit on one phase will give a greater capacity than two V's, as is indicated in Table I.

Six transformers, connected in three parallel V groups, will give but 86.6 percent of the capacity which can be obtained from the same transformers connected in two parallel delta groups. Hence, three V groups should always be changed over to two delta groups.

In any case, however, on account of the loss of capacity and the poorer regulation, the V combinations should be used only

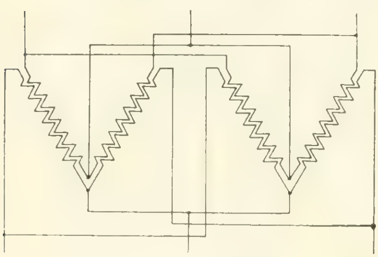


FIG. 1 (CORRECT)

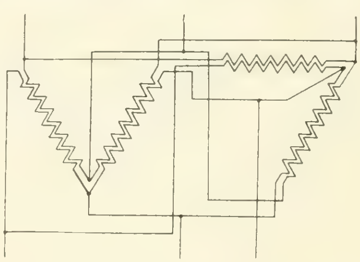


FIG. 2 (INCORRECT)

Showing correct and incorrect methods of connecting two V-connected groups of similar transformers.

where, in spite of these considerations, the connection is warranted, such as in case of the failure of one unit in a delta group, or where the temporary use of two units will give satisfactory service until the third is replaced.

The reason for the loss in capacity when using these connections is that the unsymmetrical grouping of the transformers causes either an abnormal phase displacement or an unequal distribution of the currents in the different units, or both. Each transformer of a V carries not only the current of the one phase but also that of the phase on which there is no transformer. If I equals the current in each phase of the load and the three phases are balanced, the total load equals $3\,I$. The current in each transformer, which is the resultant of the current of its own

phase and of the open phase, equals $1.73I$, since the two components are 60 degrees apart. The total transformer capacity is, therefore, two times $1.73I = 3.46I$, but the load carried is only $3I$. The capacity of the V group is therefore $\frac{3}{3.46}$ or 86.6 percent of the total single-phase rating of the transformers of the group. (See Fig. 3.)

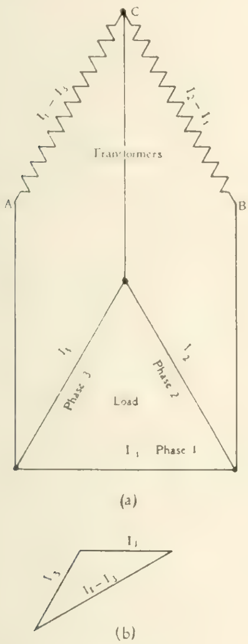


FIG. 3

a—V-connected transformers on three-phase load with balanced e.m.f's.

b—Vector diagram showing current in one unit, which equals vector sum of current in its own and the "open" phase.

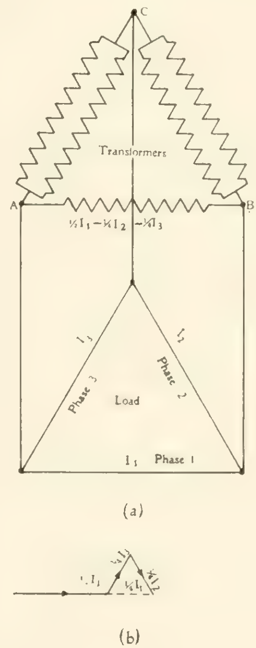


FIG. 4

a—Paralleled V and delta groups on three-phase load with balanced e.m.f's.

b—Vector diagram showing current in unit *AB*, which equals vector sum of various components in the three phases.

When a delta group and a V group are connected in parallel, on a three-phase load (See Fig. 4), there are two units on two phases but only one on the other. It is assumed that all transformers have the same characteristics and that balanced three-phase e.m.f. is impressed. Two parallel circuits are open to the

current of each phase, viz., *AB* and *ACB* for phase *1*, *BC* and *BAC* for phase *2*; *CA* and *CBA* for phase *3*. The current for each phase will, of course, divide inversely as the impedances of the two parallel circuits. If *Z* equals the impedance of one transformer, Z ÷ 2 will be the impedance of the two in parallel. Thus the impedances of the parts of the circuits will be as follows: $AB = Z$ and $ACB = Z$; $BC = \frac{Z}{2}$ and $BAC = Z + \frac{Z}{2} = \frac{3Z}{2}$; $CA = \frac{Z}{2}$ and $CBA = Z + \frac{Z}{2} = \frac{3Z}{2}$. The current distribution of the separate phases will first be considered, still referring to Fig. 1, I_1 the current of phase *1*, will divided equally between *AB* and *ACB* (since $Z_{AB} = Z_{ACB}$). Three-quarters of the current I_2, will flow through *BC* and one-quarter through *BAC*, (since $Z_{BC} = 1/3\, Z_{BAC}$). Likewise, three-quarters of the current of phase *3* will flow through *CA* and one-quarter through *CBA* (since $Z_{CA} = 1/3\, Z_{CBA}$). When more than one phase is loaded this distribution is in no way altered; the currents of the different phases are superimposed on each other in the different windings so that the total current in any winding is the resultant of all the currents produced by the separate phases in that winding.

Transformer *AB*, because it is alone on phase *1*, will carry the greatest current of any unit in the group. Hence the capacity of the group is determined when the current in this transformer is known. As explained above, the total current in transformer *AB* consists of one-half of the current from phase *1* and one-fourth of the current from each of the other two phases. These components added together in proper phase relation (See Fig. 4) are equal to three-fourths of the current of phase *1*.

If the current of each phase equals *I*, the total load handled by the transformer group equals $3I$. Since the current in transformer *AB*, the unit which limits the capacity of the group, is $0.75\,I$, and there are five similar transformers in the group the single-phase rating is $5 \times 0.75\,I$ or $3.75\,I$. The capacity of the group in percent of single-phase rating is, therefore $\frac{3I}{3.75I}$ or 80 percent as shown in Table I.

STATIC STRAINS IN HIGH-TENSION CIRCUITS
(Concluded)

PERCY H. THOMAS

In the previous discussion the author has endeavored to show that dangerous static effects result directly from very abrupt changes of potential. They may appear in parts of the circuit very remote from the existing cause. These static strains are phenomena such as would be expected to result from well known laws governing static electricity. In addition to the causes of abrupt changes of potential, already discussed, a few more will be briefly described.

(a)—*Short-Circuits* — A short-circuit between the two line wires, when of a sudden nature, causes an abrupt reduction to zero of the potential of one or both lines at the point of short circuit. This is the reverse of the case of charging a line. A wave is sent along the line, causing a dropping of the potential, which of course has no tendency to ground apparatus. Nevertheless, this wave causes just as severe a strain on the insulation between turns of the transformer coils next to line as a charging wave, for the potential of the transformer terminals is abruptly reduced. Since the inner layers cannot get rid of their charge immediately, there is a momentary potential across the coils between a high potential point in the inner layers and a low potential point at the terminal.

(b)—*Grounds*—Grounds are also a cause of abrupt change of potential and short circuits. The same strain on coils is produced as before, strongest on the side of the circuit where the ground occurs; also, the ungrounded lines are raised to full potential above the earth. It is true that the rise of potential of the ungrounded lines is not necessarily as abrupt, since it is produced partly by the generator.

It must be remembered that the static waves produced in lines by grounds and short circuits may have their intensity doubled at a reflecting point, so that the short circuit strain on coils is doubly severe at such points. However, the strains to ground are not great in these cases, except on the ungrounded wires.

It must be remembered that when a wave is caused by grounding or charging a line, the abrupt change of potential may some-

times be only the voltage existing between line and ground in that system and not the full line voltage.

In much of the previous discussion, transmission lines have been assumed to be single-phase. The conclusions arrived at are nearly all applicable to polyphase lines as well, with occasional changes which will be evident on inspection.

(c)—*Lightning*—Lightning is the best known cause of static disturbances. Unlike grounds, short circuits and switching, lightning usually does not act directly on the circuit, but indirectly by induction. Its effects, however, are of the same nature as those already discussed.

In general, lightning may affect a transmission line in two ways; by induction and direct by stroke.

(1) A lightning discharge in the neighborhood of an electric circuit but not actually reaching the circuit acts upon it indirectly by a combination of static and dynamic induction. The actual intensity of the effect in the circuits depends on the energy of the lightning discharge, on the distance to the circuit, its form and its position relative to the discharge path of the lightning and upon other conditions.

Lightning discharges are usually of an oscillating nature, that is, the charge on the cloud oscillates backward and forward between cloud and earth several times, pausing at each end of its path in each oscillation. This oscillating charge acts inductively on any electric circuit which is in the neighborhood, first (static induction), when pausing at either end of its path, by attracting a charge of the opposite sign to the nearest point of the circuit, and second (electromagnetic induction), since the actual discharge is a current and sets up an opposing e.m.f. in any parallel conductor. As the lightning charge appears first at one end and then at the other of its discharge path, it draws the charge on the line back and forth, and the e.m.f. in the line induced by the current in the discharge is in such a direction as to accelerate the motion of the attracted charge. Therefore, the effect of the lightning discharge is to cause a static wave or a series of static waves in the line. These waves are similar in general character to those produced by switching, etc., except that there is no limit to their maximum possible strength. They may produce either grounds on windings or short circuits in coils, as circumstances may determine. The static strains produced in a circuit by lightning have no direct relation to the generator voltage, but are

determined by the form and location of the line, the protective devices and the nature of the lightning discharge.

(2) A lightning discharge may and occasionally does strike a line directly. In this case it is commonly supposed that nothing can save the apparatus from injury. This may or may not be the fact, according to circumstances. If the discharge strikes the line at some distance from the apparatus, there is a very good chance that no harm may be done, for the choking effect of the line is enormous for the extremely abrupt charge of a direct stroke. That is, the discharge cannot pass down a long line quickly, and instead will pile up voltage at the point where the line is struck and finally make some direct path to earth, usually by jumping to a pole. This relieves the line and no severe shock is sent to the station. The escaping discharge may or may not destroy the pole, according to the nature of the pole and the intensity of the discharge. But although the chief discharge passes to earth directly there will be a wave sent along the line, which may or may not do damage, according to circumstances; thus, in this case the arresters are not required to discharge the direct stroke.

On the other hand, if the stroke is near the apparatus it is probable that protection will not be obtained from any lightning arrester. Even though the arrester were, for the moment, a direct connection between line and ground, there would be sufficient resistance and inductance in the ground connection and the discharge path in the earth itself, to prevent an absolutely free discharge and the result would be that the lightning would find other paths to ground. The case of a direct stroke by lightning near a station very rarely occurs.

(d)—*Paralleling Out of Phase*—One more case of static may be mentioned. When two lines are thrown in parallel out of step there is an abrupt change of potential produced when the second leg of the paralleling switch is closed. This voltage change may run up to double line voltage if the generators are directly opposite in phase. The same effects may be produced when two generators are running in parallel by opening all the poles of the paralleling-switch except one, for the machines soon get out of step, and a discharge may pass between circuits—either over arresters or elsewhere. In this case a synchronous motor or rotary converter will act as a generator for a sufficient length of time to cause a possible damage.

The most frequent causes of dangerous static disturbances in high-tension circuits have been discussed. It is evident, however,

that anything which causes an abrupt change of static potential of considerable severity may cause a dangerous strain on apparatus.

(e)—*Resonance*—Resonance does not, strictly speaking, come under the head of "static," but to show its relation to the actions already discussed, some attention will be given to it. As already frequently stated, any condenser discharging through inductance (the resistance being small) has an oscillating discharge as a pendulum has an oscillating motion. If now an alternating e.m.f. be applied in the discharge circuit of the condenser in such a way that the e.m.f. alternates just as often as the condenser discharges and is always in the same direction as this discharge, the intensity of the oscillations will get greater and greater, just as the vibrations of the pendulum will get greater and greater, as an alternating force is applied to it in such a way as always to increase its swing. There is no limit theoretically to the voltage that may be reached after a sufficient number of oscillations, if there are no losses. However, in any actual trial, the loss of energy in resistance and elsewhere gets greater as the oscillations get greater and will finally equal the energy put in by the alternating e.m.f. and thus stop the increase of voltage. Also, the exciting e.m.f. may slowly get out of step and so, after building up the oscillations for a while, reduce them again. The increase of voltage may be stopped by a break-down of insulation which may occur on account of the high voltage. That is, if we have an oscillating circuit (as, for example, a short transmission line) and an exciting cause of exactly the right frequency a very high voltage may result. The exciting cause may be either the generator e.m.f. or it may be some static e.m.f.; for example, another discharging condenser. In very few cases in actual installations, however, has it been directly shown that resonance has caused any serious rise of potential. There is no justification for hastily assigning resonance as the cause for unexplained static phenomena.

The number of complete oscillations per second in a circuit consisting of a choke coil and condenser $= \frac{1}{2} \pi \sqrt{LC}$. So, for the circuit to have a frequency of 60 cycles would require that the product of its capacity and inductance equal $1/(2\pi 60)^2$. If the capacity equals 10 microfarads the inductance must equal 7/10 henries, which is a large value. This shows that resonance with the generator e.m.f. is very unlikely in high tension lines. A condenser of 1/10 microfarad with a coil of 1/1000 of a henry has 16 000 complete oscillations per second.

When an alternating e.m.f. is applied to a long transmission

line, however, the action is somewhat different from that of a simple condenser. The first alternation of the e.m.f. sends a wave down the line which is reflected back if the end is open. If the applied e.m.f. is just slow enough so that as it starts on its negative swing, the reflected wave is just beginning to arrive again at the starting point, its e.m.f. is added to that of the impressed voltage, and a second wave of double strength is sent along the line. When the next alternation is reflected back, the applied e.m.f. has reversed and again adds to the amplitude of the wave; thus, just as with a simple condenser, an excessive voltage will be built up if there are no losses. But suppose that the generator has three times this frequency. The applied e.m.f. will then have the same relative value when the first wave reaches the beginning of the line after reflection as when it has only one-third the frequency, though two other wave crests—one positive, one negative—have been sent into the line. The amplitude of the first wave will then be doubled as before and the same with the two succeeding waves. But by this time the first augmented wave has again been reflected and reached the starting point so that it has a further increase of amplitude. The same thing occurs if the applied e.m.f. has its frequency increased to five times its original value, only five waves are operated on in a group instead of three as in the previous case; similarly with 7, 9, etc., times the original frequency (which was such that in the time of one alteration a wave would pass the length of the line and return). Resonance of this type is much more likely to occur with a long line than with a simple condenser, for the number of frequencies at which resonance may occur is greater.

If the periodicity of the applied e.m.f. is not exactly right for resonance (this applies to long and short lines), there will still be a certain amount of rise of potential which will be less as the e.m.f. departs further from the proper frequency.

PROVISION AGAINST BREAKDOWN DUE TO ORDINARY STATIC STRAINS IN MODERN TRANSFORMERS

In the modern transformer, close attention is given to the insulation between turns and layers on all coils that are directly connected through the outlet terminals to the transmission line. These end or line coils should not carry taps and they should be so arranged that the lead to the outlet bushing is from the outer or last turn. Taps should be placed near the electrical center of the winding and their number kept as low as possible. The advantages

of this arrangement are obviously that the problem of properly insulating the end coils is simplified and the possibility of high voltages on inactive parts of the winding is obviated. The insulation between turns may be graded so that it will be the same at the inner part of the end coil as in the main portion of the transformer winding. The point where the extra insulation terminates may be within the end coil or at some point in another coil, depending on the total number of coils and the length of conductor. Transformer windings designed to be divided into parts and connected in multiple or series-multiple for various voltages, will have more end or line coils than when designed for one voltage. It is obvious that this will increase the complication and cost to a considerable degree. The methods of obtaining extra strength between turns and the materials used, vary with the size and form of conductor. Coils of round wire are not insulated in the same manner as those having rectangular conductors. The amount of material used varies with the size and form of conductor, the normal volts per turn, the voltage of the transmission line, and mechanical considerations.

Emphasis is here given to the fact that the mere puncturing voltage of the material is not the most important consideration in its selection. The properties that make an insulating material desirable are:—Applicability to the particular location in which it is used so that it will be capable of successfully resisting mechanical injury; ability to withstand treatment (baking or impregnating) without deterioration; freedom from injurious chemicals; ability to withstand the mechanical stresses imposed while winding and assembling into the complete transformer; freedom from injury at the operating temperature of the transformer; and a sufficient dielectric strength.

A fact that is little appreciated is that there is no method of imposing a high test on the insulation between turns in the completed transformer. The normal stress between turns in the largest transformer is generally less that 75 volts. The insulation on the end turns can easily be made to withstand 10 000 volts. This is many times the voltage that can be impressed between turns on a complete transformer. Sample coils made up with the same insulation between turns as is regularly used on transformers, and cut through so that tests can be made between turns by separating the cut ends, will give an indication of the dielectric strength. These tests together with the experience gained from transformers which have given long, uninterrupted service, constitute the only reliable source

of information for determining the proper insulation between turns and layers.

SUMMARY

(1) When a "dead" transformer is connected to a live line a strain may be produced on the layers of the coil next to the terminal, which may be as great as the line voltage.

(2) When a short line is charged suddenly from live bus bars, a momentary voltage rise may be produced which will be not more than double voltage.

(3) When a long line is charged a strain similar to that in the short line is produced, doubling the potential first at the end of the line and afterward along the whole length. This result assumes that the charging terminal of the line is abruptly raised to full normal potential and rigidly maintained there until the wave is fully formed, also that the losses are zero.

(4) The fundamental principles governing the charging of a cable are the same as those of a transmission line.

(5) Opening an unloaded high-tension circuit may be nearly the equivalent of charging the circuit, since before the line is completely freed from the bus-bars it is often momentarily recharged several times.

(6) When a branch line of small electrostatic capacity is supplied from a main line, the rise of potential at the farther end may be twice as great as at the end of the main line.

(7) In addition to switching, other causes of static strains are grounding, short circuit, lightning, etc., when these cause abrupt changes of potential.

(8) A rise of potential due to resonance is always possible, but generally improbable. It requires that there be an oscillating circuit and an exciting cause which must be of very nearly the same frequency as the oscillating circuit. When an alternating e.m.f. of high frequency is applied to a long line the danger that resonance will occur is usually greatest, as it may be produced by a large number of frequencies.

(9) High voltage transformers should be so designed as to possess a good and constant factor of safety, both in the outlet terminals and between turns of the parts of the winding which are next to these line terminals. This can usually be accomplished by providing extra insulation on the end portions of the windings and by eliminating all voltage taps from these parts of the windings, confining them to the inner turns of the windings.

INSPECTION OF CAR EQUIPMENT ON ELECTRIC RAILWAYS

M. B. LAMBERT

THE first and most important requisite in maintaining electric car equipments in such condition that there will be as few interruptions of service as possible, combined with the least cost for repairs and minimum holding of cars in repair shops, is a system of periodic routine inspection and car overhauling. On a steam road inspection usually means the services of "car knockers," the employees located at terminals or division points who make hurried inspection of trucks, wheels, brakes and draft gear, and, if these are satisfactory, allow the trains to proceed. A number of interurban roads maintain a similar method of inspection; but, unfortunately, some interurban roads consider such superficial inspection all that is necessary and depend on these men to make hurried repairs of a patch-up nature during lay-over times and keep the cars going, sending them to the repair shop only when the repairs are beyond the ability of the inspector. This system works fairly well with new equipments and is liked by the transportation departments because it permits the use of cars whenever and wherever wanted without annoyance or delays caused by taking out of service for inspection a car that will run, and sometimes, as they say, getting a bad car in its place.

It has been repeatedly demonstrated that this kind of inspection is not adequate. In the long run every car on a system becomes unreliable, due entirely to continued "patch-up" repairs, resulting in frequent failures on the line and, in most cases, in doubling the maintenance.

The above system was, to a certain extent, handed down from the steam roads, and on some electric railways at the present time there is found one or more inspectors upon whom everybody in the transportation departments depends because he can repair cars which fail to operate satisfactorily, with little or no delay. Reference is made to this because of the bearing it has on the following and also because it clearly illustrates the point that, on such roads, the equipments have been allowed to run down, permitting numerous little details to be neglected which

would have required only a few minutes to correct. The inspectors above mentioned, having become familiar with all the weak points, know about where to look for the trouble, and under such conditions are almost indispensable. However, they seldom make repairs of a permanent nature. The newer and more profitable method is to have systematic and periodic inspections, sufficiently frequent and thorough to detect slight defects and prevent trouble.

The frequency of inspection periods as well as of general overhauling must be determined by the service conditions and the equipment. Some roads have established a mileage system; others inspect every five or ten days; a few inspect every three days. The general overhauling periods are usually determined by the life of the armature bearings, pinions, commutators, wear of trucks, brakes, etc.

INSPECTIONS

In general, every five days, or after approximately every 800 or 1 200 miles of running, each car should be brought into the inspection shop and have every detail part examined, wiped clean and given such attention as the case may warrant. All wearing parts, such as contact tips, pins, hinges, shunts, cotter keys, carbon brushes, arc shields, etc., should be renewed if the indications are that they will not keep in good condition until the next inspection. This is an element which is against the longer inspection periods, because of the greater liability, in the latter case, that parts will be thrown away before they are entirely worn out. Its importance must be determined, as previously suggested, by the value of such parts on different equipments. Lubrication of bearings should be attended to, and, in fact, practically everything on the car should be put in shape to run until the next inspection without additional attention other than to take up the brakes or to change brake shoes.

GENERAL OVERHAULING

A general overhauling should be given to each car about once a year, at which time every part of the equipment ought to be thoroughly examined. On old cars the main wiring, where not enclosed in conduit, should be examined and given a good coat of insulating paint. Cleating, etc., should be gone over to prevent vibration or chafing which might result in short-circuiting or grounding, thus risking damage or loss of the car by fire.

Motors should be opened up, bearings renewed, and housings tightened (even if only a few thousandths of an inch), armatures tested, and commutators trued up and rebanded (since old bands become loose, due to stretching of the wire at high speeds and also to shrinking of the insulation). Field coils should be tested and securely tightened in place and everything about the motor insulation should receive a good coat of insulating paint. Undercutting the mica on commutators is giving very satisfactory results on practically on all classes of motors, particularly on motors with adjustable spring tension brush holders. Motor lead wires or resistance wires should not be permitted to hang loosely or chafe against motor or truck frames. It is almost always possible to fasten them by cleats so that they will not chafe against iron parts in any way and still provide ample slack for curves.

Armature repair shops should be provided with alternating-current voltage up to 2 500 volts in order to make proper insulation tests. For testing rewound armatures or armatures being overhauled for short-circuits, etc., the writer recommends the method devised by Mr. A. Daus, of the Metropolitan West Side Railway Company, Chicago, in which alternating-current equal to full load is supplied directly to the armature at low voltage for a few seconds by special contacts on the commutator at normal brush separation. By this method the effect of a short-circuited or an open coil is very pronounced. Minor defects, as for instance, a drop of solder across two commutator segments or risers, will frequently clear themselves, and poor contacts, which might remain unnoticed by other methods, will rapidly heat under the heavy current and can be detected by the hand. From 60 to 80 volts is ordinarily required to force full-load current through a 500 volt armature.*

Trucks and brakes are really the most important part of any high-speed electrical equipment, as failure of either contributes largely to wrecks, derailments, etc. The general overhauling period should therefore be determined more by the condition of trucks and brake rigging, brake cylinders and compressors than by anything else, as badly worn hangers, pins and chafing plates, journal boxes, etc., on trucks, are apt to cause sufficient looseness to the truck frame to impair its safety at high speed, around

*For a similar method of testing armatures see "Experience on the Road," by Leonard Work, in the JOURNAL for January, 1910, page 79.

curves, over frogs, etc. On the other hand, weakened brake rods, pins, etc., on brake apparatus are apt to give way in an emergency application, and worn leathers in the brake cylinder will leak so badly that the proper effect of the air pressure is not secured. Worn pump cylinders will also affect the pressure. It is probably needless to say that every part of the trucks, brake rigging and compressors should be thoroughly overhauled at these periods.

Controllers, Heaters, Lights, Etc., if not in conduit, ought to receive the most minute examination in order to detect evidence of chafing, vibration, etc. There is a much greater risk of fire from smaller wiring than from larger, as the larger wires will not break so easily and in case of short-circuit will open the breaker while the smaller wires are more apt to break and usually cause a small arc where the break occurs, which is liable to ignite adjacent inflammable material.

All parts of controllers, heaters and light sockets should be put in first-class shape so that at the intervening inspection periods it will only be necessary to keep the apparatus in operating shape until the next period of general overhauling. If the general overhauling is carried out carelessly it will simply mean additional force and expense at the inspection barns and hurried inspections, as the time which should be devoted to careful scrutiny and inspection of parts is taken up in making repairs, which should have been fixed up more permanently at overhauling time.

It will readily be seen that on systems where the general overhauling is under the management of one man and the inspection shops under another, there is considerable opportunity for each to blame the other for failures on the road. When one man is directly responsible for all repair work he is more liable to secure the best possible general overhauling in order to secure the greatest reliability in service and lowest inspection cost, as it is now well known that, considering the fact that reliability in service is paramount, it results in much greater economy to do the best possible work at the general repair shop when the parts are removed from the car than to make renewals and repairs to the apparatus on the cars where the time required is largely increased, due to inconvenience and lack of facilities at the inspection shops.

REPORTS

To secure the best results from inspections it is necessary to check up the efficiencies of various departments, methods, etc., and to place the responsibility for failures of equipment. To most readily accomplish this, the following system of reports, forms, etc., is recommended. It must be appreciated, however, that local shop methods may require variations from these forms which can best be determined by analysis of local conditions.

First of all, the transportation departments are naturally most interested in the reliability of cars in service and consequently the responsibility of seeing that the cars are taken out of service and placed in the shops when due for inspection should be theirs. In order to do this effectively, an inspection

FORM I—TRANSPORTATION DEPARTMENT.

WEEKLY REPORT OF CARS OVERDUE FOR INSPECTION.

Car Number	Date Due for Inspection	Date Taken Off For Inspection	Cause of Delay	Mileage Since Last Inspection	Remarks

board or chart should be maintained at the chief dispatcher's office, similar to a locomotive chart or board on steam roads, arranged and kept up so that this official may know each day what cars are due for inspection and arrange to place them in the shop. If the inspection shops get behind in their work and cannot handle the car that day, the dispatcher, of course, must arrange to keep it in service until it can be inspected. A weekly report to the general superintendent should be made by the dispatcher, giving the number of the cars and the number of days each car was held in service beyond regular inspection time. This may be similar to Form I from which the general superintendent can see at a glance each week how the inspection barns are keeping up with the work and thus can intelligently interview them regarding the causes of delays.

The second and only regular report which should be necessary from the transportation department relating to the equipment, should be a weekly or monthly report, such as indicated by

Form II, showing the number of cars taken out of service due to failure, and stating briefly the nature of the defects. This will show the frequency with which cars are taken off between regular inspections and indicate faulty inspection.

FORM II—TRANSPORTATION DEPARTMENT.

WEEKLY REPORT OF CARS TAKEN OUT OF SERVICE DUE TO FAILURE.

Car Number	Date Taken Out of Service	Defect Reported by Motor-man	Detention in Minutes	Date of Last Inspection	Remarks

The master mechanic or general foreman should make a weekly report to the general superintendent, showing the following:

Car number
Date taken out of serivce
Defect reported
Date placed in shop
Defect found
Date sent out of shop
Date previously inspected
Date of previous overhauling
Cause of delay in shop
Remarks

This report, if properly carried out, will place in a brief form, before the general superintendent each week, the following information:

1—Length of time between failure on the road and date placed in shop.

2—The difference between what motormen report as the defect and what is actually found to be the cause.

3—The length of time it took the shop to get the car repaired and again in service. In cases where a car is kept in the shop for a long time, it should appear on the reports each week showing date placed in shop, and under the column "date in shop," the information *still in shop* should be entered in the report.

4—The length of time since last inspection or general overhauling before a failure on the road occurred. This is extremely important as it is the only reasonable way to check up the work of each individual inspector. It is possible to a large extent to determine by common sense whether the failure of any detail of a modern car equipment, except, perhaps, a grounded armature or field, could have been prevented by a proper inspection. The very fact that with the above form of report each inspector's

work will be shown up, tends to make them more careful. In other words, if the car fails on the road a day or two after inspection, due to a broken shunt, motor lead chafing and grounding, or a rheostat wire breaking due to vibration, or any of the things which common sense will show could not have developed in one or two days, the inspector whose duty it was to take care of that detail will obviously be guilty of neglect. It is usually better to have weekly reports, as the volume of data to be entered is then seldom very large and careful preparation of the report does not become a disagreeable task. Wherever possible, a healthy competition between various inspection shops should be encouraged, sending each foreman a monthly statement showing the quantities of material used by each shop and labor cost for inspection for a given number of cars, also the percentage of failures of cars in service from each shop.

FORM III—REPAIR AND INSPECTION DEPARTMENTS.

WEEKLY REPORT OF CAR FAILURES IN SERVICE.

Car Number	Date Taken Out of Service	Date Placed in Shop	Date Sent Out of Shop	Defect Reported	Defect Found	Date of Previous Inspection	Name or No. of Inspector	Date of Previous Overhauling	Cause of Delay in Shop	Remarks

The storekeepers should be held responsible for carrying a stock of standard parts, and when cars are held in shop waiting for simple parts which should have been in stock, the cause of delay will appear on the monthly report, Form III, under column "Remarks." In order to assist the storekeeper in carrying a minimum stock the master mechanic should supply him with a list of materials consumed every month. With a systematic inspection this will not vary greatly. For unusual parts, the master mechanic will have to post the storekeeper, taking into consideration the time from date of requisition necessary for delivery.

One or two roads have established a material chart for recording daily the parts used on inspection of cars at each inspection shop for the purpose of checking the material actually applied to the cars and the quantities issued by the storekeeper

each month. Any dishonest appropriation of material can thus be determined, as no inspector would allow items to be entered on the chart which were not used on his particular part of the work, since it is to his interest to keep the quantity of material on the comparison sheet as low as possible, consistent with reliability in service. This chart is merely a large sheet of heavy paper posted on a suitable board or on the wall of the shop, with a column for each class of material used at inspection, and each night the inspector makes a check mark showing the number of parts used; for instance, if he used four contact tips on controllers, under this heading he would enter ////, etc. At the end of each month the cards are sent to the general superintendent or the master mechanic and totals are drawn off which show, for comparative purposes, exactly how much material was used at each shop on the different kinds of equipment.

In addition there are, of course, numerous reports which the master mechanic or general foreman should make to the general superintendent, showing cost of car-body repairs, painting, varnishing and car cleaning per month, also a statement showing the total number of defects per month on different sizes and classes of motors, trucks, and air compressors, such as the number of grounded armatures, number of grounded fields, number of broken pinions, number of broken gears, number of grounded brush holders, etc. These statements should show such items compared with corresponding figures for the previous month, and for the same month of the previous year, on the same number of cars in service; different schedules, of course, affect the comparisons. The principal object of such a statement is to show whether the defects are increasing unduly and whether the master mechanic is taking proper steps to cope with the trouble, etc. If any detail appears to be unduly expensive to maintain and is causing frequent failures in service, the general superintendent can take steps to get advice from the manufacturers of such parts or to get information from some other railway using similar apparatus with a view of remedying excessive maintenance costs.

Such a system of reports as outlined above will be of great value to the superintendent or general manager in helping him to analyze and compare costs, to minimize expensive and annoying interruptions to service, and, by properly placing the responsibility, to prevent avoidable breakdowns.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

407—Determining Ratio of Inverted Series Transformers for Use in Meter Testing—For the calibration of a 600 ampere, 600 volt, direct-current Thompson recording wattmeter, there is available a 110 volt alternating-current circuit, two 40 to 1 series transformers, a 5 to 1 potential transformer, and a 5, 10, 20, 40 ampere induction rotating type standard test meter. The series transformers have to be inverted to obtain the required current capacity for the service meter. In order to obtain the ratio of the series transformers used in this way, readings were taken with the two following sets of connections. In each case the desired load was obtained by the use of lamps on the 110 volt alternating-current circuit. The low current windings of the two series transformers were connected in series on one side of this circuit and the heavy current windings were paralleled. In each case the potential coil of the standard meter was connected independently across the 110 volt circuit and the potential coil of the service meter was connected to the secondary of the shunt transformer, which had its primary connected across the 110 volt circuit, thereby giving 550 volts to the potential coil of the service meter. In the first case the series coils of both meters were connected in series across the paralleled secondaries of the inverted series transformer. In the second case only the series coil of the service meter was connected in this way, the series coil of the standard meter being inserted in series with the low current coils of the two series transformers so that it would carry the current supplied to the lamp load. With the first connection the service meter was calibrated by reference to the standard meter on a 50 ampere load. The connections were then changed to the second arrangement and the load adjusted to again give 50 amperes on the standard meter. As both meters registered the same, with the first arrangement of connections, the difference in their registration with the second method of connection was assumed to give the ratio of the series transformers. Multipliers thus being determined, the calibration of the service meter was completed with the second arrangement of connections. Is this method commercially accurate, and, if so, within what load limits? F. H. G.

This method of calibration would not give even commercially satisfactory results for two fundamental reasons. The first of these is that because of there being more or less of impedance introduced by the series coils of Thompson meters when used for measuring alternating-current power, especially in the larger capacity types, they require separate calibrations for use on alternating current and direct current, notwithstanding the fact that they are constructed without the use of magnetic iron. There is liable to be a discrepancy amounting to from ten to twenty percent on this account. Secondly, a transformer ratio determined as is outlined in the question for inverted series transformers is applicable at only the load at which the determination is made. In order to calibrate the service meter by reference to the standard meter a

new ratio or multiplier would have to be determined corresponding to each load throughout the range of the service meter. The reason for this is that, with the series transformers inverted, their ratio is seriously affected by variation in either the resistance or impedance of the heavy current circuit. Thus the effect of introducing an impedance such as that of the standard meter in one arrangement of connections and omitting it in the second arrangement would be liable to result in a discrepancy in the ratio of the series transformers between no load and full load amounting to perhaps 20 percent. When a series transformer is used in this way the available e. m. f. in the heavy current circuit is very small. The difficulty due to the necessity of separate calibration on alternating-current and direct-current cannot be avoided. H. B. T.

408—Stress in Wire of a Transmission Line — Given a wind pressure of one pound per foot and a weight of one pound per foot of wire in a transmission line of long span, what is the resultant stress in the wire? Is it equal to $1+1=2$ lbs. or $\sqrt{1^2+1^2}$ lbs.? E. J. L.

The expression $\sqrt{1^2+1^2}$ is correct, as the stress is the resultant of the two components. These may be solved graphically by representing the two stresses as the two sides of a rectangle (in this case a square), the resultant stress, $\sqrt{2}$ lbs., being represented by the diagonal of the rectangle. T. V.

409—Internal Temperature in Mercury Vapor Lamps — (a) Have any pyrometric measurements been made on the mercury vapor lamps (both Cooper-Hewitt and quartz tube) to indicate the actual temperatures which are obtained in use? (b) In the quartz mercury vapor lamp I have noted that investigators claim the center of the cross-section of the vapor is the greatest light-giving source—it being very much "whiter" in quality than the rest of the area. Does this indicate a considerably higher temperature or is it a "pinch effect" of some sort or the result of both? (c) I can see how the temperature will be greater at the center, because of heat loss by radiation from the surface of the tube, which cools the adjacent area and thereby reduces its conductivity and, also, due to the current tending therefore to concentrate in the center and raise the temperature at this point to a still greater value. (d) If this latter explanation is true, then the explanation of the greater light-emitting power of the "core" is clear, but it would seem that there would be reason for some doubt as to the possibility of a sufficient difference in temperature from core to outside areas to account for a difference in light-giving powers. J. G. Z.

The temperature in the center of the quartz tube is estimated at about 6 000 to 7 000 degrees C. at one atmospheric pressure of the mercury vapor, the center of the tube, of course, being very much hotter than the mercury vapor coming in contact with the walls of the tube; the temperature of the latter is estimated to be 1 300 to 1 400 degrees C. at one atmosphere mercury vapor pressure. The temperatures of the Cooper-Hewitt lamp are very much lower and are, in the normally operating lamp, between 160 and 290 degrees C. Further information regarding pyrometric measurements made on the mercury vapor lamps is to be found in an article by A. P. Willis, in the *Electrician* (London), Vol. 54, 1904, p. 26; also in an article by Kuech & Retschinsky, *Amalen d Physik*, 1907, Vol. 22. J. C. P.

410—Power-Factor Correction—In transmitting three-phase, 6 600 volt, 60-cycle power a distance of 12 miles, the power to be used for industrial service along the line, and about 300 hp., the largest single amount, at the farthest end of the line, what would be the best method of bringing up power-factor? Part of the load is for railway service, fluctuating between zero and 400 hp., with

100 hp. average. Would transformers and rotary converters be preferable to motor-generator sets with exciters? How would initial cost compare? With synchronous apparatus of sufficient capacity, would it be advisable to install one equipment without a reserve, using it 18 hours a day? Could lighting service be taken from the 6 600 volt circuit without seriously unbalancing the phase? R. P.

Rotaries should never be used for power-factor correction since they should be operated at as near 100 percent power-factor at large loads, as possible. At lower power-factors the armature copper losses increase markedly. Use a synchrononous motor-generator set at the end of the line. The question of reserve capacity is one which would be decided entirely by the amount which you are willing to invest in insurance against interruption of service. If single-phase lighting load is placed on one phase of the primary circuit, the unbalancing will be proportional to this load. If there is sufficient lighting load to justify the distribution of this load equally upon the three phases by means of the necessary number of lighting transformers, serious unbalancing can, of course, be avoided. However, the low power-factor and voltage fluctuations which will result, due to the motor load, render such a circuit undesirable for lighting service. F. D. N. & E. C. S.

411—Grounding vs. Insulating of Switchboard Frames—When surrounded by a floor of re-enforced concrete, should the frame of a switchboard be grounded or should it be insulated? The switchboard in question controls two 400 volt, three-phase rotary converters which furnish current to the railway circuit. C. L. C.

There is a difference of opinion among engineers regarding the question of grounding switchboard frames. The best practice, however, according to most authorities, is to ground all frames where the voltage of the system is 750 volts or greater. Some railway switchboards operating at 750 volts are not grounded. The switchboards for lower voltage than this are insulated from the building. It will be found that many switchboards of the lower voltages have their frames grounded and the engineers claim that it is advisable to protect operators from getting shocked. On the other hand, if the frame is grounded, there is more liability of damage to the apparatus from lightning which would have a tendency to discharge through the switchboard apparatus to the grounded frame, and destroy the apparatus; on this account most manufacturers supply insulated turn buckles in the wall braces, and the switchboard can then be insulated by placing the channel iron on a wooden base when insulation is required. It is held that the danger to operators from shocks at the low voltage is not as great as the liability of damage to apparatus by its becoming grounded to the frame through leakage or lightning discharge. If the feeder lines are not subjected to lightning, the argument against the grounded frame is not so strong. The use of a dry insulating covering for the floor immediately around the switchboard is to be strongly recommended, especially in case the frame is ungrounded. The whole question is one which must be settled by the station engineer according to the condition existing at the plant. B. P. R.

412—Expansion and Contraction of Expanded Steel Railway Rails—In welding steel railway tracks in cities that have several miles of straight track, how is the expansion and contraction of rails provided for? H. W. R.

Experience has indicated that where railway tracks are imbedded in the pavement of city streets the temperature of the rails is maintained within sufficient limits to obviate serious distortion due to expansion and contraction, thus making it possible to weld the rails without providing expansion joints. Moreover, a substantial pavement aids in holding the rails

rigidly in place, especially when concrete and cement are used in connection with the ballast to fill the space around the web of the rail, between the head and the lower flange. Welding is seldom attempted in the case of interurban or other roads employing open track construction. T. V.

413—Fan Motor Field Coils Used for Inductive Load in Meter Testing—What is the best way of arranging nine coils taken from old fan motors to give a maximum range of inductive load in small steps for use in testing meters? H. W. R.

Connect the nine coils in series with single-pole, double-throw switch inserted between each two coils, the respective coils being connected at the middle point of each switch. Connect the free terminal of the first coil to one side of the leading circuit and likewise the free terminal of the last coil of the series to the other side of the loading circuit. Connect all the upper points of the double-throw switches to one side of the loading circuit and all of the lower points to the other side of the loading circuit. Limit the maximum voltage applied to the loading circuit to that which any one coil will stand. By representing these connections diagramically it will be apparent that, by means of the double-throw switches, coils may be connected in series, in multiple or in series-multiple connection across the loading circuit. This method of connection is often employed in the construction of resistance racks for use in the testing of various electrical apparatus on the test floor as a convenient method of loading. H. B. T.

414—Effect of Flickering on the Life of Carbon Filament Lamps—How would the life of a 119 volt carbon filament lamp be affected by a continuous flickering caused by a constant fluctuation of the supply voltage between 122 and 116 volts? C. R. F.

An increase in voltage of three percent above the normal voltage for which the lamp is selected has the effect of reducing its life about 50 percent, while a corresponding decrease in voltage tends to increase its life about 75 percent. However, lamps of standard quality are so rated that they will give the guaranteed life without difficulty if the voltage fluctuations are maintained within approximately two percent of normal voltage. When the fluctuations above and below normal are about the same in magnitude and duration, the tendency is obviously for the two effects to counterbalance one another, the life probably being shortened a nominal amount. It may be noted also, that on a voltage three percent above normal, the candle-power of the lamp is increased by about 18 percent and the watts per candle are reduced by ten percent, i. e., the lamp is being operated at a higher efficiency. Likewise, with a voltage three percent below normal, the candle-power is but 85 percent of the rated candle-power and the watts per candle are increased by about 9.5 percent. B. F. F.

415—Effect of Increased Railway Voltage on Current Consumption—A city district is supplied with power for electric railways from a power station situated at such distance from the center of load that the average voltage in the district is 400 volts. The amperes flowing are determined from the station feeder ammeters. If a converter sub-station is installed at the center of load of the district, giving the cars over the section an average voltage of 550, and if running time, loading, number of cars, etc., are the same, how would the number of amperes supplied by the sub-station compare with the number supplied by the power-station? C. A. H.

With 550 volts on the line and the same current as before through the motors, the motorman will be able to accelerate to a higher speed than with the lower voltage. Consequently he will be able to cut off power sooner and coast a larger percentage of the total time. By increasing the time of coast, he may be able to reduce the average ampere consumption as much as 15

percent with the increase in line voltage specified. This reduction is based on the assumption that the service remains the same in all respects except those mentioned, i. e., the same schedule speed is to be maintained and the average length of stop is to be the same, and that the sub-station alone is to supply the power, without assistance from direct-current generators in the power-house. O. M. J.

416—**Ground or Short-Circuit in Alternator**—A delta-connected, revolving field type, three-phase, 6 600 volt alternator had a grounded armature coil which could not be detected when the machine was examined. The machine was run slowly and gradually excited. Smoke soon indicated the damaged spot. When a new coil had been substituted, the machine showed clear of grounds. Why did current flow when the machine was entirely open-circuited and there was only one spot grounded? C. A. H.

The fact that sufficient current was induced in the damaged coil to cause noticeable burning would indicate either that the coil was connected to the iron at two points, thereby making a closed circuit, or what is more probable, that it was short-circuited as well as grounded. F. D. N.

417—**Influence of Relative Position on Magnetizing Effect**—If a bar of iron two inches in diameter is placed against a bus-bar carrying 2 000 amperes, what would be the difference in the magnetizing effect of the current in the bus-bar with the iron bar placed with its axis at right angles to the length of the bus-bar and its middle point adjacent to the conductor first, at its edge, and, second, along its width. C. A. H.

It may be said in general that the magnetizing effect would be greater with the iron bar in the second position because a greater proportion of the magnetic lines of force emanating from the bus-bar, due to the flow of current, would pass through the entire length of the iron, i. e., the amount of leakage through the air would be less than in the first case. In order to make a quantitative comparison, it would be necessary to determine the permeability of the iron is question and integrate calculated values of magnetic intensity at various unit areas throughout the dimensions of the iron piece, which would obviously be a complicated problem. H. W. B.

418—**Potential Above Ground of Ungrounded Circuit**—Assuming that an alternator is operating at full voltage with no part of its circuit grounded, would a person touching the live wires with good contact feel a shock? If so, what proportion of the line voltage would he receive? R. C. B.

The static conditions in a transmission circuit have been explained in articles by Mr. R. P. Jackson (see the JOURNAL for February 1908 p. 85). As noted therein, the conditions of the three-phase circuit may be represented in relation to the potential to ground of all its parts, by a triangle rotating about its center, this "potential center" being at ground potential. When contact is made at a given point on the circuit, the person constitutes a partial ground on the wire which is touched and the potential center of the system is no longer stable but an alternating difference of potential is established between it and the earth. This means that the average potential of the three wires of the circuit is first positive and then negative, relative to the earth. The amount of this unbalance of potential depends on the voltage of the line and the resistance offered by the person who constitutes the ground. The charging current which will flow through this ground will depend on the frequency and on the capacity of the line, and the voltage across the person in contact with the line will be the product of this charging current and his resistance. On high voltage circuits such a proceeding would be hazardous even if perfect insulation were attainable. H. M. S.

419—Effect of Change of Frequency on Meter Reading—In changing from a frequency of 125 cycles to 60 cycles on a 110 volt circuit, will the accuracy of a 5 ampere, 100-110 volt, 125 cycle, type E Schaeffer recording wattmeter be affected? What effect will it have on 10 and 20 ampere meters of this type? Is it possible to use 125 cycle, Thomson ammeters and voltmeters on 60 cycle circuits without involving any errors in the readings? A. J. A.

It may be said in general that meters depending upon the action of the meter current on a movable disc or vane are affected by changes in frequency; whereas, meters of the movable coil (dynamometer) type are not so affected. The Schaeffer meter, being of the disc type, will not register correctly on 60 cycles if built and calibrated for 125 cycles. If it is recalibrated on 60 cycles it will read correctly on this frequency at unity power-factor; but on low power-factor it will read incorrectly. Meters provided with a frequency adjustment will read with equal accuracy on either frequency when adjusted and calibrated for the desired frequency. This is explained in an article by Mr. H. Miller in the Journal for October, 1907, p. 596. Ammeters and voltmeters having moving vanes are not correct on any frequency alternating current other than that for which they are calibrated. A. W. C.

420—Correction of Power-Factor by Over-Exciting Rotary Converters—Assume the installation of a 200 kw. rotary on a low power-factor circuit. The direct-current load on this rotary converter never exceeds 50 kw. By over-exciting the field on this machine can the power-factor of the circuit be corrected to the same extent as would be posible with a 200 kw. synchronous motor with 50 kw. mechanical load? E. A. W.

In case the rotary and the synchronous motor were identical as far as field margin and short-circuit ratio are concerned, they would have approximately the same abilty to raise the power-factor of the system to which they are connected. In most cases, however, it is not advisable to operate rotary converters at low-power-factors, thus introducing leading or lagging wattless currents in the armature winding. When operated in this way most rotaries will heat up considerably, and, further, the armature curent will react on the field flux, causing a distortion of the same, and thus sparking will take place. Rotaries are usually built to operate at approximately unity power-factor, and manufacturers, as a rule, do not guarantee satisfactory operation at any lower power-factor. J. B. W.

421—Operating Characteristics of Alternating-Current Rectifiers—What is the lowest alternating-current voltage that can be rectified by a mercury vapor converter, or by an aluminum or other electrolytic rectifier? Please give data regarding this class of apparatus, such as maximum and minimum voltages, both alternating-current and resulting direct-current, resistance, counter-e.m.f., and efficiencies. P. H. T.

The lowest alternating-current voltage on which a mercury rectifier will operate is that which will just supply the drops in the bulb and so make short-circuit operation possible. The shape of the bulb, its temperature, and the degree of vacuum all influence this drop, as explained in an article by Mr. R. P. Jackson, in the Journal for May, 1909, p. 264. The alternating-current voltage required to supply a given direct-current drop may be approximated by the formula: A.C. volts=(D.C. volts+bulb drop) ÷0.45. (The bulb drop ranges from 12 to 20 volts.) An electrolytic cell can be made to rectify or partially rectify alternating voltages from the feeblest to the highest voltage, depending upon the form of the cell or cells, the electrolyte, the temperature, etc. Low voltages may

be partially rectified by the usual aluminum cell, but internal resistance and drops will prohibit drawing any appreciable current from the cell. High voltages may be rectified by a series system of electrolytic cells. The ratio of alternating-current voltage and direct-current voltage is dependent upon the shape and size of plates, the current density, the electrolyte, temperature condition of plates, and the power-factor. The efficiency and regulation obtained depend also upon the above characteristics and may prove to be poor. No definite performance data can be given, as the operation of the cell is so dependent upon the special conditions of mechanical and chemical design, load, temperature and voltage. For detecting very feeble alternating voltages by rectification, a contact rectifier may be used as described in reprint No. 94, Bulletin of Bureau of Standards. H. M. S & L. W. C.

422—Selection of Fuses for Motors—What is the proper capacity of fuse for use in the main circuit of an alternating-current motor of 50 hp. capacity, the circuit being 220 volt, three-phase, 60 cycles; both with and without auto-starter? The motor is direct-connected to a direct-current generator. Is there a formula which may be applied for either two-phase or three-phase circuits and for power-factors of 100 percent or less. What other conditions affect the capacity of fuses? F. H. W.

For use on 50 hp, 60-cycle motors provided with auto-starters, fuses of 200 amperes would be suitable for the running circuit and 350 amperes for the starting circuit; if auto-starters are not used, fuses of 600 ampere capacity should be employed. We know of no such formula. For further information note Nos. 9, 10, 50, 323 and 367; also article on "Fuses," by Mr. Dean Harvey, in the Journal for March, 1906, p. 159. The capacity of fuse required depends in general on whether the motor is started light or under load, whether it is to be fused in the starting or in the running circuit, and to what extent it is desired to fuse for overload. It should be noted that when fusing in the starting circuit, the protection afforded the motor against continuous overload is not very good. Motors for industrial service are generally fused at 50 percent above full-load current for running conditions and two and one-half or three times the full-load current for starting conditions. Complete information regarding the use of fuses may be obtained by reference to the National Electrical Code, section 8b. G. L. C.

423—Series Field Shunt for Direct-Current Generator—Please give formula for calculating the required resistance and cross section of the German silver ribbon for series field adjustment of a compound-wound, direct-current generator; given size of machine, voltage and resistance of the series fields. For example, what sized shunt will be required to adjust the compounding of a 300 kw machine to give 110 volts at no-load and 122 volts at full load? The speed is 125 r. p. m. There are two and one-half turns in the series field. Its resistance is 0.00086 cold, 0.00109 hot. W. A. B.

Series field shunts are usually cut and adjusted on the test floor, with the generator operating at a fixed speed and loaded under definite and constant conditions. No attempt is made to calculate them, although approximate preliminary calculations may be made when the machine is being designed. The generator is originally designed with sufficient ampere-turns to keep the voltage on full load within reasonable range of its no-load voltage, so that, by adjusting the series field shunt, any degree of compounding within this range may be obtained. The cutting of the correct shunt with the minimum amount of waste material is a matter of experience. Unless one is very certain as to the size of shunt necessary, or has a large amount of German silver strap on hand so that several trials can be

made, the following method is to be recommended: Provide a field shunt of liberal dimensions made of soft sheet iron and make the necessary trials to obtain the desired compounding. When this shunt is found to be correct, its resistance can be measured, and a German silver shunt of the same resistance substituted, care being taken that it has sufficient carrying capacity to conduct its share of the current without becoming seriously overheated. Some manufacturers use annealed sheet iron for their permanent shunts, and if it has liberal dimensions, good results are obtained in operation. In making adjustments to determine the proper shunt to use in a given case, it should be noted that, when a shunt gives correct compounding but runs too hot, it should be replaced by one of larger cross-section and correspondingly greater length, to give the same total resistance. In other words, shortening the shunt decreases the compounding and at the same time increases the heating of the shunt, while reducing the cross-section of the shunt increases the compounding. L. A. M.

424—**Division of Load on Direct-Current Generators**—Two Siemens & Halske, 220 volt, direct-current, direct-connected generators are operated in parallel, running at 100 r. p. m. One machine has an ampere capacity of 300 amperes, while the other has a capacity of 210 amperes. When they are connected in parallel the large machine will take 300 amperes and the smaller 124 amperes. How can the latter be made to carry its portion of the load? We have tried the expedient of speeding up the engine to which the smaller machine is direct-conected, but this does not give the desired results. G. I. M'F.

Two compound-wound, direct-current machines which have compound curves of the same shape, will divide their load properly when the resistance of the series coils are inversely proportional to the capacities of the machines. Under these conditions it is evident that when each series field is carrying its proportion of the load, the voltage drop on both series fields will be the same. In order to obtain this condition in the above case it is necessary to insert a resistance of proper ohmic value and suitable current carrying capacity in series with the series field of the large machine. The effect of this will be to increase the current in the series field of the small machine, and reduce the current in the series field of the large machine. Hence, by properly adjusting the amount of this extra resistance the machine can be made to divide the load as desired. See "Parallel Operation of Machines with Series Fields," by H. L. Beach, in the JOURNAL for November, 1909, p. 681. It is assumed in the above that the compound curves of the machines coincide throughout. To parallel machines having dissimilar compound curves, the fields may be adjusted so that the voltages of the two machines will agree at least at no load and full load, thus approximating the same shape of compound curve. D. H.

425—**Improving Regulation of Alternator**—I was recently called upon to inspect a generator, to determine the cause of its failure to hold voltage under load. A 100 kw., 220 volt, 60-cycle, two-phase inductor-type generator is belt-connected to a 250 hp. four-cylinder gas engine and operates at 900 r. p. m. On full load the voltage could not be maintained above 205 to 210 volts, even with all the exciter field rheostats cut out. The speed was all right; hence a watt-meter was placed in the circuit and an actual load of 80 kw, with an apparent load of 128 kw, was indicated, i. e., a power-factor of 62.5 percent. There is a spare belted type, 50 kw., 220-volt, 60-cycle, two-phase, 1 200 r. p. m. revolving field generator at this plant. Would it not be practicable to use it in one of the departments as a synchronous motor and, by applying sufficient field, to cause it to serve in correcting the power-factor of the system? The group system of drive is used and a large number of motors are not

running at full load; in fact some are only slightly loaded. The shop in which I propose to use the spare generator would give a load of 30 to 36 hp., i. e., approximately 25 kw. Thus the synchronous motor would be carrying about 50 percent mechanical load. This machine is of quite recent design. If used in this way could it be started from the alternating-current side, a friction clutch being used to throw on the load, or would you recommend the use of a starting motor; if so, what size would be required? As there is ample over-load capacity in the prime mover, there apparently would be no objection to large starting current. I figure that the power-factor could be raised to about 85 percent, thus allowing additional mechanical load on the main generator. F. R. P.

As noted in 366, in Jan., 1910, issue, it is advisable to adopt induction motors as nearly as possible to the power requirements, thereby increasing the load on each motor and thus improving the power-factor. Assuming that a re-arrangement of motors is impracticable, and with the load and other conditions as stated in the question, the 50 kw alternating-current generator may be operated as a synchronous condenser. It will serve to raise the power-factor to approximately 88 percent providing the 25 kw mechanical load is additional to the present motor load. If the synchronous condenser is replacing the 25 kw induction motor load, operating at 62.5 percent power-factor, it will raise the power-factor to approximately 95 percent. It would be advisable to use a starting motor (about 10 hp) to obviate unnecessary overloading when starting the synchronous condenser. The most economical arrangement involving the use of a synchronous condenser is that in which the wattless component or the power of the machine equals the real (power) component. It may be noted that on an ordinary standard synchronous machine, the field current at zero power factor is approximately 150 percent of its value at 100 percent power-factor. The corrective effect of course depends on the field current, which, in turn, is limited by the temperature or by the I R drop in the field winding. These points will be of assistance in obtaining satisfactory adjustment of field strength in the synchronous condenser to obtain the best operating conditions, and at the same time avoid over-heating in the field of the machine. Fig. 425 (a) represents the graphic vector solution of the two foregoing cases. (See article on "Graphic Calculator," by Mr. C. I. Young, Vol. IV., p. 627, Nov., '07, and No. 353, Dec., '09.) Triangle *A* represents the case in which a mechanical load of

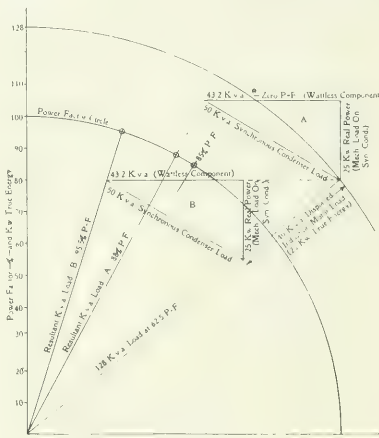


FIG. 425 (a)

25 kw is added to the induction motor load. Triangle *B* represents the case in which a 25 kw mechanical load replaces an equivalent induction motor load. The various k. v. a. capacities, the real and wattless components involved in the problem, and the resulting power-factors and total generator k. v. a. load are indicated in the diagram. The point of intersection of the line representing total k. v. a. load and the power-factor circle determines the vertical coördinate representing the resulting power-factor. It will be noted that in neither case is the total generator load as great when the synchronous condenser is employed as when it is omitted. S. N. C.

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Cost and Value of Light

The distribution of light from incandescent lamps is the theme of two articles in this issue by Mr. Rolpr and Mr. Clewell. Little is said about cost. Mr. Clewell gives approximately $28.00, $88.00 and $163.00 as the annual cost for lighting an office containing six people, six hours per day with electricity at one, five and ten cents per kilowatt-hour respectively. Assume, for instance, the intermediate figure, which would also be about the cost for three hours per day with a rate of ten cents per kilowatt-hour. This is approximately an average condition if the office has good windows and there be but little night work. Now $88.00 per year for six persons is about $15.00 per person per year or $1.25 per month. If the average wage be $62.50 per month, the cost of light is two percent of the wages. This is the cost for good light; if poor light cost say half as much, then the difference between the cost of good light and of poor light is one percent of the wages. If the good light increases the efficiency of the workers by more than one percent it pays. One percent of an office day is about five minutes. If better light enables manuscript or notes to be read with greater ease and figures to be read more accurately, if there is greater rapidity and fewer errors, if there is less eye-strain, less headache, greater comfort and satisfaction, so that more and better work is done in eight hours than would have been done in eight hours and five minutes with the poor light, then the extra cost is justified. If the cost of current is one cent per kilowatt-hour, then the necessary gain is correspondingly less. It is difficult to measure the exact effect of superior general conditions, but if better light and better vision, less fatigue and more cheerful surroundings cause an effect which is appreciable, surely it must be more than one percent—it is probably ten, and possibly fifty percent.

The effect of good light is perhaps more readily seen in the factory than in the office. In the early hours of winter mornings and the late hours of the day, employees are apt to be quite slow if the light is poor. Men cannot work as rapidly nor as accurately when the

light is dim and the surroundings are depressing. Brightness is stimulating. Some foremen estimate that good light gives a gain of from half an hour to an hour or more per day. The cost of power for factory lighting is usually quite low. In a certain case, the cost of good light was found to be about one cent per day per man, where the wages were $3.00 per day. One cent is the wage for two minutes. Considering workmen simply as machines, it is self-evident that if good light is worth anything, it certainly is worth many times what it costs.

The cost of installation should not be a controlling factor in choosing between the best and the cheapest. The fixed charges due to the first cost are apt to be relatively small. Mr. Clewell finds that his sample office cost about $30.00 to equip, and that the difference between satisfactory and unsatisfactory methods was insignificant. Even if the annual fixed charges be assumed at twenty percent, they are only $6.00, which is very small compared with the total annual cost, $28.00, $88.00 or $163.00, depending upon the cost of power.

It follows that any arrangement, which incerases the effectiveness of the lighting or the economy of operation, may easily justify a considerable initial expenditure. Often the best is also the cheapest. In one case tungsten lamps were installed without reflectors. It was found that two lamps with reflectors gave twice as much illumination on the work as three lamps without reflectors. Hence the desired result was secured by seemingly expensive reflectors, at less first cost and far less cost for current.

Conditions vary so widely that general conclusions are of questionable value. In a given case, it is well to determine whether the initial cost of a first-class installation, or the cost of rearranging an old installation in order to secure the best illumination results, is not relatively small compared with the total operating cost, and whether the total cost of good illumination is not relatively small compared with the gain in quantity and quality of output which it brings about. Cost and excellence are not necessarily proportional. Intelligent and scientific design of the illumination may bring far better results and at the same time a reduction in cost.

To determine the real value of good illumination where commercial production is involved, either in the office or in the factory, the cost of the light should be determined in terms of the total cost of production, either the labor alone, or the labor plus the various other charges which enter into the total cost of production. This may be expressed either in percent or in minutes. The value of the

illumination should be measured by the increase in quantity or quality of output. Often this is difficult to measure. It may be a result of more or less indirect influences such as less fatigue, or the stimulus that comes from cheerful surroundings or the reduced liability to errors and mistakes. It may be difficult to demonstrate beforehand just how much this advantage amounts to in dollars and cents, but the common sense judgment of a broad gauge superintendent is a better guide than detailed estimates of cost which fail to include the indirect and really important elements which make good illumination worth while.

CHAS. F. SCOTT

Concrete Construction and the Erection Engineer

The old adage "Jack of all trades" finds few more apt applications than in the work of the erection engineer in the electrical field. In the early days, which are not very far past, the man who was familiar with ordinary electrical connections and who knew where both ends of a wire belonged and had in addition a little experience in overcoming the feverish conditions which electrical machines would sometimes develop, was equipped for erection work. As the machinery increased in size, the old belt-driven units gave way to large direct-connected generators too large for shipment complete. Accordingly, generators had to be built up and wound at the place of installation; flywheels had to be assembled, and armatures had to be pressed on shafts. This work required an expert, experienced as a machinist and rigger.

The development of switchboard work following the introduction of electric control for switches and rheostats and the multitude of small wires for various instruments, opened up the field of concealed conduit work for control circuits. This brought with it the problems of plumbing and pipe fitting, which are very important features of erection work in large modern power plants. The necessity for fireproof material for high-tension construction has resulted in the concrete switchboard structure and, consequently, the erection engineer has had to master the problems of form work and concrete mixing.

Instead of having to deal with large quantities of concrete calling for simple and rough form work, such as for foundations, sewers and floors, which chiefly requires figuring on the mixtures and quality of materials, the pourings for high-tension structures are small and difficult to make. These structures are made up of

small cells, barriers and shelves, with many openings for switch and insulator supports, thus making the question of form work an important feature.

As switchboard structures often occupy conspicuous positions in power houses and become objects of observation and comment, great care must be taken to have all edges and angles of shelving and barrier work true and level, and of a pleasing appearance, aside from the fact that the apparatus to be inserted requires accurate dimensions in all parts. Moreover, accurate work is necessary in securing proper insulation distances between the live metal parts of the disconnecting switches, bus-bars, etc., of the structure. Ordinarily the concrete is considered to be the same as a ground and proper clearance distances are required.

On account of these features, contractors for ordinary concrete work are very cautious about undertaking the construction of such switchboard structures. There is so little of this work required in any one place, in most instances, that the local contractor either does not care to attempt to do the work or else he wants to be paid dearly for his experiments. The erection engineer is therefore often compelled to build such structures with whatever labor he can obtain.

It is from this point of view that the article by Mr. Stinemetz, in the present issue of the Journal, is written. The type of structure upon which his description and illlustrations are based differs from that described by Mr. Chubbuck in the December issue chiefly in that the latter is suitable for high voltages and large capacities, whereas the present type of structure is intended for use in stations of more moderate capacity.

With slight modifications, structures of this type may be adapted to any capacities within the limits for enclosed cell work prescribed by good engineering practice. Accordingly, as all of these types of structure are somewhat analogous, the various points covered by Messrs. Stinemetz and Chubbuck are generally applicable, but each type of structure involves variations as regards details of procedure.

Provision should always be made for circuit breaker tie rods, anchor bolts, conduits for the secondary and control wiring, etc. They are ordinarily placed in proper position in the forms before pouring the concrete. The inner surface of forms should always be prepared by covering them with some waterproofing material such as linseed oil, paraffine or soap. This is a necessary expedient,

whether the forms are to be used for one operation or repeatedly, as it prevents the moisture in the concrete from penetrating the wood, and thus avoids both warping of the forms and, what may be more troublesome, adhesion of the concrete. By following this precaution the work of preparing the forms for subsequent use may be very materially simplified. Any one of these materials will doubtless be found effective; the most easily applied will probably be soft soap, as it can be put on the forms quickly with a brush.

Further stress might have been placed upon the ultimate economy of a reasonable investment in good lumber for use in the construction of the forms for those parts of the structure requiring precise results. The full importance of this point has been brought home to many an erection engineer only after costly experience. Judging from the analysis of costs in the present case, the saving in labor by providing good workable material is obvious, especially in view of the fact that the work may be carried on so as to allow of the repeated use of forms.

The use of metal reinforcement in connection with concrete construction is becoming more and more general. The type of reinforcement applicable to a given case is clearly a question of adaptability. The prime advantages in its use are the saving effected in material, due to thinner walls, shelves and barriers, the increased strength of the structure, and the improved appearance incident to the neater design.

The use of substantial steel forms for the circuit breaker cells and some of the barrier sections is beyond doubt entirely feasible and has the advantage of insuring accurate results and the elimination of considerable expense for material and for the labor of building and erecting wooden forms. Mr. Stephen Q. Hayes, in an article in the April issue, brings out the point that foreign practice recognizes the possibilities of standardization in the construction of switch gear compartments and transformer houses, when built in considerable numbers. Apparently elaborate forms are employed, but with slight additional expense owing to their repeated use. This method, however, introduces the question of availability, as brought out by Mr. Stinemetz, delays in securing the desired forms being expensive and otherwise objectionable. The use of standard forms also precludes deviations from standard designs, even though, in some cases, slight departures from standard arrangements would make a more satisfactory finished structure.

Systems of Railway Electrification

Evolution is the process of adaptation to the environment. The individual organism, the individual plant, the individual animal, is not perfect, it is no better than it need be to hold its own against the antagonistic influence of the environment in the struggle for existence. The art of engineering progresses by a like process of evolution; it adaps its products to the environment; and these products are no better than they need be to hold their own.

As in nature evolution is marked by diversification, so in our art we encounter diversification of system with variable external conditions. And, dropping our biological parabole, we see in the wide diversification of the systems of electrification of railroads in this country and in Europe the attempt of their designers to meet the local conditions in the best manner or, perhaps more correctly speaking, in the least unsatisfactory manner.

Electric railways had been operated for over ten years by direct current, before, some fourteen years ago, the first three-phase surface cars were operated in the city of Lugano in Switzerland. This installation proved successful and was shortly followed by the rack-and-pinion mountain roads on the Gorner Grat and the Jungfrau operated by three-phase alternating current. These stupendous engineering undertakings attracted much attention because of the boldness of their conception and because of the singularly beautiful and majestic landscapes which their construction made accessible to those who, through lack of physical power or endurance, could not otherwise have seen with their own eyes the majestic scenery of the Alps from a height of fourteen thousand feet.

But while the feat was great, which was thus performed by the civil and electrical engineers, the adaptation of the three-phase current to trunk line railroads had not commended itself strongly to the engineering profession. There was in the induction motor the inherent difficulty of speed regulation to contend with, and the awkward double trolley. The first objection was partly met by the connection of two induction motors in tandem, as on the Valtellina Railway, while the second problem was at least amenable to great improvement in details. When the great Simplon Tunnel was planned, connecting, underneath the Alps, the north and south of Europe, it was decided to use three-phase locomotives of the Valtellina type. At the same time, in this country, the Grand Trunk Railway adopted single-phase locomotives for the Sarnia Tunnel; while the New York Central Railroad adopted direct current for the electrification of its

New York terminals, and the New York, New Haven and Hartford Railroad successfully employed the single-phase system.

Which is right and which is wrong? What an idle question this seems to be, and how rarely is this question asked sincerely! In reviewing before our minds the discussion of the past half dozen years on this subject, it would seem as if the disputants did not ask, "Which is right, and which is wrong?" but rather, "Who is right and who is wrong?" The policy of the truly able engineer, railroad man, and financier will be one of openness of mind toward a problem as yet imperfectly solved.

The article on "Three-Phase Railways in Europe," in this issue of the JOURNAL, is from the pen of one of the most talented engineers and designers of three-phase motors, who is well competent to review the three-phase railways on the continent of Europe. The four-speed locomotives recently furnished for the Simplon Tunnel are well described. This construction, depriving, as it does, the three-phase motor of the one-speed characteristic and giving it a multi-speed characteristic, if it continues to prove successful, may aid in gaining a field for the three-phase motor in heavy traction work.

The entire subject is most interesting and fascinating and deserves careful attention. Meanwhile there remains a broad field in this country, as well as abroad, for the exploitation of the direct current, the single-phase, and the three-phase current for the electrification of different types of railways. B. A. BEHREND

Voltage Adjustment of Electric Systems in Parallel

In dealing with the paralleling of alternating-current systems, in this issue of the JOURNAL, Mr. Lincoln considers the subject in an apt and vivid manner. He deals with the question from the standpoint of the amount of power which passes between the two systems, and indicates safeguards which are desirable to prevent the overloading of the connecting link. He points out that a motor-generator set in which there is an induction element affords a means by which power can be interchanged when the frequencies are not identical, thus allowing a flexibility which goes far towards removing the difficulties which would otherwise exist.

There is another phase of the question which Mr. Lincoln does not discuss. If two sytems are to be connected together by transformers, it is also essential that there be a proper voltage adjustment in addition to the power adjustment which is primarily dependent upon the governors and speed characteristics of the prime movers.

Each system tends to produce a certain voltage. If these voltages are not equal before synchronizing, there will be a flow of "out of phase" current when the switches are closed, which will tend to lower the voltage of one system and raise that of the other. In each system the voltage is controlled by the aggregate field current of its synchronous machines. If, therefore, the field currents in one system are relatively small, there will be a flow of equalizing or magnetizing current so that the excess field effect of the other system is transmitted to it in very much the same way that the excess power is transmitted from one side to the other side under the requirements established by the governors of the engines and the water wheels. It is possible, therefore, even when the power adjustments are satisfactory and the wattmeter on the connecting link gives the desired indication, that there still may be an improper adjustment of field currents which tends to cause unequal voltage, with the result that an extra or equalizing current flows between the two systems. Such a current will be indicated by an ammeter in the connecting link, and bears a 90 degree relation to the power current. As the capacity of the transformers by which the two systems may be joined depends upon the current and not merely upon the power transmitted, it is obvious that voltage adjustment is of great importance; scarcely less important than the power adjustment.

One method of adjustment is by changing the ratio of the transformers connecting the two systems. This ratio may require readjustment with changes in the load on either system. Unless this adjustment be made, a coöperation between the power station attendants is essential. Otherwise there may be a tendency on the one part to keep raising the voltage and on the other to keep lowering the voltage, which would cause a wider variance instead of a closer agreement.

In some cases, it may be possible to find a normal, average condition of working, which will not require constant attendance at the point of connection between the systems or between the operators. In general, however, particularly when the operating conditions are subject to wide variations, it will be desirable to have means of inter-communication, so that the operations in different stations can be, in effect, under the supervision of one chief operator.

Where the systems are inter-connected by a motor-generator set, either induction or synchronous, the problem is simply one of power and not of voltage, as the e.m.f.'s and the power-factors of the two systems are in this case independent of one another.

Chas. F. Scott

REFLECTORS FOR INCANDESCENT LAMPS

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THE object of this article is to give briefly the advantages of the use of reflectors with incandescent lamps and to give also a few considerations in regard to their use. No attempt has been made to give complete directions for installing reflectors, as such directions can usually be obtained from the manufacturers. However, certain data has been included, which, it is hoped, will be of value to those who have lighting systems to design, as supplementing the general formulæ for installing reflectors.

Accessories used to change the character of the light or illumination received from light-sources may be divided into three classes, —globes, shades and reflectors.

1—Globes are enclosing or partly enclosing accessories which may or may not have a favorable effect on the distribution of the light obtained from the light-source.

2—Shades are partly enclosing accessories used to protect the eyes from the brilliancy of the light-source or to add to the appearance of the installation. Usually they do not have a favorable effect on the distribution of light.

3—Reflectors are accessories which change the distribution of light by means of reflection.

The object of using reflectors is to obtain better illumination than could be obtained without them. Three factors in illumination can be improved by their use, viz:—

Efficiency,
Appearance,
Eye-protection.

These factors are almost invariably inter-related and in any individual case should not be considered separately. However, in treating them generally they may be considered separately.

The principal purpose of reflectors is to obtain higher efficiency. The increase in efficiency which can be effected by their proper use is often surprising to one not familiar with the subject. An ordinary bare incandescent lamp throws practically as much light upward as downward. This allows as much light to reach the ceiling and upper walls as reaches the plane of illumination. Some of this light is reflected downward, but the quantity so reflected is small un-

less the walls and ceiling are very light in color. The coefficients of reflection (percent of incident light reflected) of a few colored papers will show this; thus white foolscap reflects 70 percent of the incident light, orange 50 percent, yellow 40 percent, pink 36 percent, light blue 25 percent, emerald green 18 percent, bluish green 12 percent, ultramarine blue 3.5 percent.* It should also be remembered that light which passes upward is often reflected several times before reaching the plane of illumination, thus causing the second or third power of the coefficient of reflection to enter as a factor.

EFFICIENCY

As photometric evidence of reflector efficiency, the light sent into the useful zone may be considered. Neglecting reflection from the ceiling and walls, the useful zone or zone of useful light is rarely greater than the zone from zero to 60 degrees, this zone being the cone-shaped surface which includes all light below 60 degrees from

TABLE I.

Source of Light.	Flux of Light, in Lumens.			Percent Increase over bare lamp.		
	0°-60°	0°-45°	0°-15°	0°-60°	0°-45°	0°-15°
Bare 60 watt Mazda or tungsten lamp.	86.8	41.6	3.1[illegible]	——	——	——
Same with Intensive Reflector . . .	221.	154.	20.3	155.	270.	536.
Same with Focusing Reflector . . .	223.	170.	32.0	157.	308.	903.

the vertical in a downward direction. The useful zone is often much smaller than this, sometimes being only the 0-15 degree zone. The latter is quite likely to be the case when lights are used close to a ceiling of considerable height. Bearing in mind the above consideration the figures given in Table I are enlightening. These figures give an idea of the immense waste of light when bare lamps are used and also the control of light effected by the use of reflectors. This control with the reflectors mentioned above allows plenty of light to reach the ceiling and walls, so that the room is not given a gloomy appearance. On the other hand, it should be remembered that light colored walls and ceilings increase the illumination more with bare lamps than with lamps and reflectors, so that the above figures can be taken as indicating exactly the increase in illumination due to reflectors.

Perhaps the best idea of the increase in efficiency due to the use

*Figures from the Standard Handbook for Electrical Engineers, p. 745.

of reflectors can be obtained from the lumens per watt constants given by Cravath and Lansingh.* The lumens per watt for a given installation is the average intensity of illumination (in foot-candles) obtained by one watt per square foot. With bare 16 c-p lamps (3.1 watts per candle) the constants given in Table II have been determined as the result of a large number of illumination tests. It will be seen that good reflectors, properly used, increase the efficiency of an installation from 38 to 200 percent, depending on conditions of use.

APPEARANCE

Passing on to a consideration of the effect of reflectors on the appearance of an installation, it may be stated that in general an improvement is effected by their use. It is true that in many installations in which the artistic side is of great importance, bare frosted

TABLE II.

Equipment.	Color of Ceiling.	Color of Walls.	Lumens per watt.
None (lamps bare)	Light	Light	.60 to 1.3
None (lamps bare)	Light	Dark	.50 to .80
Clear prismatic reflectors	Light	Light	1.8
Clear prismatic reflectors	Light	Dark	1.5
Opal dome or cone reflectors . . .	Light	Light	1.7
Opal dome or cone reflectors . . .	Light	Dark	1.4

lamps (usually round) are used to obtain effects which could not be obtained by other means. Here reflectors, even of the best artistic design and used with fixtures designed especially for them, would not always successfully replace bare lamps. It is also true that reflectors, designed purely for utilitarian purposes are sometimes used where more than mere efficiency is necessary, with inartistic results. For the great majority of installations, however, artistic and efficient reflectors can be obtained which, if properly used, will present a much more attractive appearance than bare lamps or even lamps equipped with diffusing (and absorbing) shades. The fulfilling of æsthetic requirements in lighting systems of the highest class usually means a certain sacrifice in efficiency. Some, and often great,

*"The Calculation of Illumination by the Flux of Light Method"—J. R. Cravath and V. R. Lansingh, in the Transactions of the Illuminating Engineering Society, Vol. III, p. 518, Oct. 1908. These constants, originally published as watts per lumen are now more commonly used as the reciprocal, lumens per watt.

sacrifice is justifiable, but the sacrifice should always be carefully weighed and its extent appreciated by the designer of the lighting system.

EYE PROTECTION

The use of reflectors for the protection of the eyes is of great importance. Lighting systems should always, if possible, have the lights well above the range of vision, but even then the effect of bare lamps is injurious to the efficiency of vision and ultimately to the eyes themselves. This is especially true of Mazda and tungsten lamps which have a high intrinsic brilliancy. In fact, the use of reflectors or some diffusing device to protect the eyes is practically necessary with Mazda and tungsten lamps, now so commonly used. The intrinsic brilliancy of the carbon lamp (3.5 watts per candle) is 375 candle-power per square inch, of the Gem lamp 625 candle-power per square inch, of the tantalum lamp 750 candle-power per square inch, while with the Mazda and tungsten lamps it runs as high as 1 000 candle-power per square inch. The construction of the eye is similar to that of a camera. The iris, by changing in size, protects the retina, on which objects seen are focused by the lens, just as the photographer protects his plates from over-exposure by regulating the size of the stop. A bright light acting on the eye causes the iris to contract and allow less light to enter. It is obvious that this will cause the objects illuminated to appear dimmer than they otherwise would, and will consequently reduce the efficiency of vision. Furthermore, the iris cannot close sufficiently to protect the retina thoroughly from a light source of such high intrinsic brilliancy as the Mazda or tungsten filament. The result is eye-strain and, ultimately, permanent injury.

It would seem to follow that indirect lighting with no light-sources exposed is best for protection of the eyes. Such a system, however, is comparatively inefficient and involves a seldom appreciated physiological factor which causes eye discomfort. The eye works with the greatest comfort if it can be directed from time to time toward objects or walls less brightly illuminated than the main portion of the room. This allows a change in the rate of chemical action in the retina, the position of the muscles governing the size of the pupil and the muscles governing the focusing of the lens. The fallacy of indirect lighting is that it provides an illumination so uniform, not only in the plane of illumination but on the walls as well, that the changes stated above are impossible or possible only in a slight degree and the eyes soon become exhausted.

Many reflectors give a desirable distribution of light and yet do not satisfactorily hide the lamp filament. Such reflectors should be avoided for exposed use with Mazda and tungsten lamps, and in fact are undesirable with any incandescent lamp. There are reflectors on the market of equal efficiency and of a deep bowl shape. When these are used with bowl-frosted lamps, the filament is completely hidden. Prismatic reflectors of this character, giving practically any distribution of light required by ordinary service, are available. It is also possible to obtain opal reflectors which similarly hide the lamp filament and have a good efficiency, although the range of distribution obtainable is more limited than with prismatic reflectors.

In the great majority of lighting systems and especially lighting systems of the commercial class (stores, offices, etc.) it is desirable to use reflectors rather than shades or globes, on account of the higher efficiency thereby obtainable. In order to secure the advantages of this higher efficiency, it is important that for each installation reflectors be carefully selected with reference to the distribution of light which they give.

THE PROBLEM OF GENERAL ILLUMINATION

Illumination problems on the whole can be divided into two classes—general illumination and local illumination. General illumination is the illumination of an area as a whole by one or more light-sources. The term is used in contradistinction to local illumination which is the independent illumination of a single object or portion of a room.

We will consider here only the problem of general illumination as affected by reflectors and their proper use. Using the flux method of calculating illumination, the problem divides itself into three steps:—First, decide on the intensity of illumination desired; second, determine the wattage necessary, and third, select the proper lamp, reflector and spacing to give uniform illumination consuming the wattage determined. The first two steps are comparatively simple, and the data necessary for carrying them out is easily obtainable.* The third is greatly simplified by a thorough understanding

*"The Calculation of Illumination by the Flux of Light Method"—J. R. Cravath and V. R Lansingh, Transactions Illuminating Engineering Society, Vol. III, p. 518, Oct., 1908.

"Tungsten Illumination," Arthur J. Sweet, in the JOURNAL for Dec., 1909, p. 740.

Bulletin 25-A, Holophane Company, Newark, Ohio.

of the spacing requirements of various reflectors. Mr. Arthur J. Sweet has divided problems of general illumination into three classes*:—

1—Illumination from a single light source.

2—Illumination from a line of light sources.

3—Illumination from multiple light sources, arranged on the basis of the square.

The reason for this classification is that the deduction of the photometric curves necessary to obtain uniform illumination is quite different when the illumination is obtained from one light source than when it is obtained from two or more light sources in a line, or four or more light sources in squares. The ideal curves for each class of general illumination have been derived by Mr. Sweet. While there are no reflectors on the market which give exactly the ideal curves, many reflectors approach certain of the curves very closely.

For the illumination of an area by a single light source, the closest approximation to the ideal results has been obtained with prismatic reflectors. Fig. 1 shows the photometric curve of an extensive type of prismatic reflector and the resulting illumination curve at a height of six feet above the plane of illumination. This curve is figured from the well-known formula, $I_h = \frac{c\text{-}p}{h^2} \cos^3 \Phi$ where I_h is the illumination in foot-candles on a horizontal plane, *c-p* is the candle-power of the light ray in the direction of the point for which the illumination is figured, *h* is the height above the plane of illumination and Φ is the angle which the light ray makes with the vertical. It will be seen that the illumination in Fig. 1 is nearly uniform over an area whose diameter is about equal to the height of the light unit. Beyond this area the intensity of illumination falls off gradually.

For the second class of general illumination, i. e., narrow rooms with a single line of light units, the best results at present obtainable are given by curves of the extensive type. For narrow stores and similar rooms coming under this class, reflectors of the extensive type should be placed at a height above the plane of illumination equal to one-half the width of the room. The distance apart should be twice the height above the plane of illumination. The illumination curve in Fig. 1 is approximately what would be obtained across the room directly underneath a light source when the units are spaced

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*"Standard Relations of Light Distribution," in the JOURNAL for November, 1909, p. 663

correctly. The reflector is at the correct height for a room 12 feet wide. If the height is increased, it is obvious that the intensity of illumination decreases and the efficiency of the installation is reduced. If the height is decreased, the intensity of illumination is increased, but the increase is greatest in the center of the room and the sides of the room become too dark with reference to the center. Similarly, if the lights are placed farther apart along the room, the intensity of illumination half-way between light sources decreases and a spot

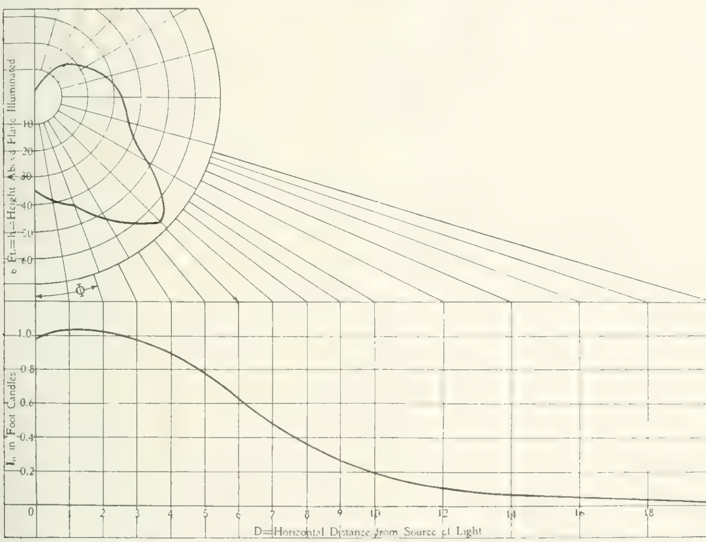


FIG. I—PHOTOMETRIC AND RESULTING ILLUMINATION CURVES OF A REFLECTOR USED FOR LIGHTING ROOMS WITH ONE LIGHT UNIT IN THE CENTER

With 60-watt bowl-frosted tungsten lamp.

effect is the result. If the lights are placed closer together, the result may or may not be harmful. The intensity of illumination will be raised, with a corresponding raise in the watts per square foot and no change in efficiency. The uniformity of illumination, however, may be unfavorably affected. Ordinarily it is safe to place the reflectors as close together as desired, but it is desirable to check the uniformity, figuring the foot-candles at several points by means of the formula used above.

The third class of general illumination problems, viz:—illumination from multiple light sources arranged on the basis of the square, is worthy of considerable attention. In distributing the light units over the ceiling, the area should be divided, as nearly as possible, into equal squares and a light unit placed at the center of each. It is

important that the units be placed at the centers of the squares and not at the corners. A common method of locating outlets is shown in Fig. 2. It is a poor method as it gives a lower intensity of illumination near the walls than in the center of the room. Fig. 3 shows the correct way to locate the same outlets.

The size of the squares depends upon the extent to which shadows of objects will be objectionable. For a given ceiling height, the smaller the squares, the less intense will be the shadows. In lighting large offices, where individual desk lights are not employed, the squares should be comparatively small in order to have the light on any one desk coming down from many units, thus eliminating shadows and decreasing the glare due to reflections from the desk. In stores, the squares need not be so small. The sizes of squares de-

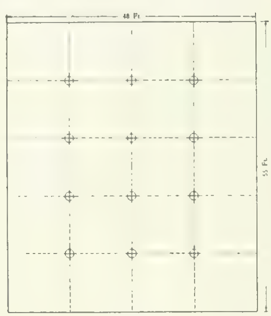


FIG. 2—INFERIOR, THOUGH COMMON METHOD OF LOCATING OUTLETS FOR GENERAL ILLUMINATION

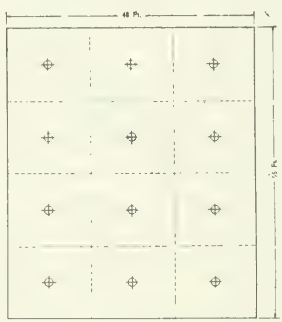


FIG. 3—CORRESPONDING CORRECT METHOD OF LOCATING OUTLETS FOR GENERAL ILLUMINATION

sirable for various spaces are given in Table III. This table cannot be strictly adhered to in all cases, and it is better not to use the largest size square available with the smallest ceiling height in each line.

The size of the squares bears no relation to the intensity of illumination, but only to the evenness of illumination and depths of shadow.* The photometric curves for this class of lighting vary according to the ratio of height above the plane of illumination to distance apart of the lights. This ratio is called k, thus,—

$$k = \frac{\text{mean distance between light units}}{\text{height above plane of illumination.}}$$

*The Ideal photometric curves for this class of lighting are given in the November, 1909, issue of the JOURNAL, in the article on "Standard Relations of Light Distribution," by Mr. Arthur J. Sweet.

For any given value of k there is a minimum curve which will give uniform illumination. For any given curve of the type ordinarily obtained with reflectors, there is a maximum value of k, which will give approximately uniform illumination. Curves are shown in Fig. 4 having four different values of k and including the ranges of k available for ordinary illumination work. They show the illumination curves obtained by the use of a 60-watt bowl-frosted Mazda or tungsten lamp, and illustrate not the ideal curves for various k values, but the proper k values for some of the curves obtained from reflectors in common use. If the lights are placed lower than the correct value calls for, the average illumination will not be uniform, being highest directly underneath the lamps. Sometimes a slight sacrifice in uniformity is permissible to obtain higher

TABLE III.

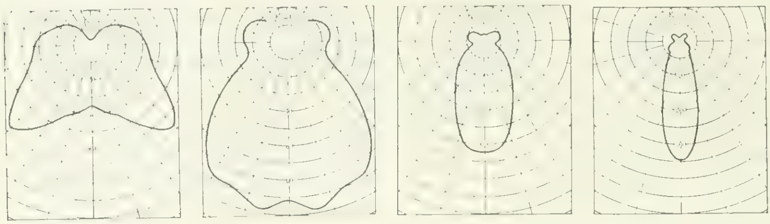
Kind of Room.	Ceiling Height.	Desirable Length of side of Square.
Armories, Auditoriums, Public Halls, Rinks, etc.	12 to 16 ft.	12 to 16 ft.
	Over 16 ft.	15 to 26 ft.
Stores	8 to 11 ft.	8 to 11 ft.
	11 to 15 ft.	10 to 16 ft.
	Over 15 ft.	14 to 22 ft.
Offices with individual desk lights	10 to 20 ft.	12 to 18 ft.
Offices without individ'l desk lights	9 to 12 ft.	7 to 11 ft.
Offices without individ'l desk lights	12 to 16 ft.	9 to 14 ft.
Offices without individ'l desk lights	Over 16 ft.	11 to 18 ft.

intensity, but it is usually better to obtain the higher intensity, if necessary, by an increase in the wattage. If the lights are placed higher than the correct value of k calls for, the illumination will usually be uniform but the intensity will be lower. Such a sacrifice in intensity is sometimes required for appearance sake, but ordinarily a reflector having the correct value of k for the height desired can be obtained.

The decrease in intensity due to increase in height of the lights applies only for a finite area; for an infinite area, there would be no decrease in intensity. In other words, the illumination would be the same for any height of the lights, providing they were above the height called for by the maximum value of k for uniform illumination with the given curve. It follows that for very large areas, the decrease in illumination, due to excessive height of the light-units, will be less than with small areas, this decrease in illumination

with small areas being due to absorption by the walls of light which, with a larger area, would build up the illumination at distant points.

An example of decrease in illumination due to excessive height, is an installation of prismatic concentrating reflectors in the generating room of the Fall River Electric Company, Fall River, Mass. The size of the room is 120 by 45 feet; the walls are dark red brick; girders, machinery, etc., are black, and the ceiling is largely skylight. The installation consists of 56 100-watt clear tungsten lamps equipped with concentrating reflectors and placed on the girders 52.5 feet above the floor. The distance between lights is fourteen feet in one direction and seven feet in the other, making the mean distance between lights 10.5 feet. The maximum, and consequently most efficient, value of k for this reflector is 0.5. The actual value of k in the installation is 0.2. In other words, the height is 2.5 times as great



K=2, Extensive Reflector K =1. 5, Intensive Reflector K =0.75 Focussing Reflector K=0 5 Concentrating Reflector

FIG. 4—PRACTICAL LIGHT DISTRIBUTION CURVES FOR DIFFERENT VALUES OF K

as it ought to be for most efficient result. An illumination test on the installation showed an average illumination of 1.68 foot-candles. This gives 1.62 effective lumens per watt. The manufacturers of the reflectors give 3.4 lumens per watt as the value which is obtained at the proper height, with dark ceiling and dark walls, which are the conditions in this installation. An increase in height of 150 percent, therefore, results in a decrease in efficiency of approximately 52 percent. The figures apply, of course, to this individual case only. As the reflector used in this installation is of the most concentrating type available, the efficiency of the installation could be increased only by lowering the lamps and reflectors, which could not be done in this case on account of the traveling crane.

Owing to the great decrease in efficiency which results from the use of reflectors at incorrect heights, it is evident that the results of any illumination test should not be accepted as indicative of the efficiency of the reflectors, unless it is shown that the reflectors are

spaced at their proper *k* value. Many illumination tests on reflector installations have been published showing results inconsistent with each other and results far lower in efficiency than that figured on, in general, by illuminating engineers. The cause of the low efficiency and the inconsistency is undoubtedly due in most cases to use of incorrect values of *k*. Under similar conditions of ceiling and walls, and with correct use of reflectors, the lumens per watt obtained from various installations should be fairly constant for a given kind of reflector. For this reason we can depend on such constants for calculating illumination. Every engineer who designs lighting systems should have at hand such constants and also the correct *k* values for all the reflectors which he uses. A more widespread use of such data will cause material increase in the efficiency of lighting systems, with no decrease in artistic results. It should be the duty of every manufacturer of reflectors to supply the lumens per watt constants and *k* values for his reflectors, just as the manufacturers of automobiles supply the data and directions necessary for using their machines to the best advantage.

NOTES ON OFFICE LIGHTING

C. E. CLEWELL

THIS paper presents a series of experiments conducted for the purpose of determining the arrangement and number of lamps required to furnish illumination best adapted to the general conditions of office lighting.

The general requirements for such lighting are:—

1—Good and sufficient light for each person.

2—An arrangement of lamps which is satisfactory, without regard to the arrangement of desks; i. e., the distribution of light should be practically uniform.

3—An installation of the lamps which will avoid eye strain.

4—A type of lamp adaptable to offices of various sizes in which various kinds of work are performed.

Two general methods may be used for approximating these requirements:—

a—One lamp may be placed over each desk close to the work, and a general overhead illumination supplied, which is sufficient for ordinary purposes.

b—The lighting may be arranged overhead in such a way as to remove the necessity for individual desk lighting.

The second of these methods is, in general, the better and more economical. Numerous experiments on the eye indicate a harmful effect from the continuous use of a single lamp placed directly over and close to the desk surface. The bright spot of light directly under the lamp is generally surrounded by a region of comparative darkness. The eye suffers from the excessive intensity of this bright spot and soon becomes fatigued since the line of vision is continually changing from the bright area to the darker surroundings. This strain on the eye can largely be avoided if the desk surface is furnished with a uniform light of moderate intensity.

In a practical investigation of office lighting, tests were made in a typical office twenty feet square with a ceiling height of eleven and one-half feet. A sectional view and floor plan of such an office is given in Fig. 1. This typical office contained six desks arranged as shown and could accommodate eight people but was occupied by only six. It was originally equipped with one large light source in the center of the ceiling and four individual carbon filament lamps for those with desks along the walls. The arrangement of lamps is

shown in Fig. 1. The complaints arising from the use of this scheme of lighting were three-fold:—

1—The general illumination was not uniform for the desks along the wall, thus making the use of individual desk lamps necessary.

2—Those who faced the large center unit suffered an excessive eye strain from its intrinsic brightness and reflection from papers.

3—Those desks supplied with individual lamps presented surfaces which were non-uniformly lighted, and excessively bright in spots.

In solving this problem the attainment of the general requirements above stated was sought by the use of general overhead lighting and the removal of all individual desk lamps.

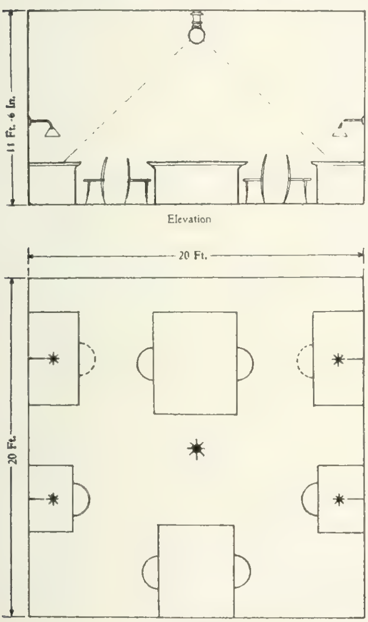


FIG. 1.

The first step towards improving conditions was the installation of four units somewhat smaller than the large central unit, arranged as indicated in Fig. 2. After trying two types of lamps according to this revised arrangement it was found that the side desks still required individual desk lamps, the overhead units being placed so as to furnish uniform light for the more central portions of the room and, as a consequence, not properly lighting the desks along the walls. This plan, therefore, did not fulfill the general requirements; first, because a change in the arrangement of desks still involved a shifting of individual desk lamps, and, second, because the size of the units chosen, while large enough to give a sufficient amount of light, still resulted in units of a size so large as to be productive of eye strain to those facing any of the four overhead lamps.

Other arrangements which were given a careful trial were as follows:—Five lamps arranged as in Fig. 2 with the addition of a central unit. A trial of this scheme showed that the eye strain of

those receiving the direct rays from the overhead lamps was still excessive and that the resulting intensity was still insufficient on the sides of the room unless the individual lamps were used.

A trial of four units spaced as in Fig. 2 and arranged so as to use the ceiling as a reflecting surface presented two new features:

First, the light while sufficient at night was not sufficient to light the desks properly when needed on dark days. This shows a necessity for more artificial light during the day than at night. While the eye is subjected to stimulus from ordinary daylight the pupil is in a contracted state making more artificial light necessary to give the impression of satisfactory illumination than when the eye is relaxed under the influence of natural darkness or of the lower intensities of artificial light to which it may be subjected. In the case of indirect lighting, however, this effect was probably due in large part to the diffusion of the resulting indirect illumination.

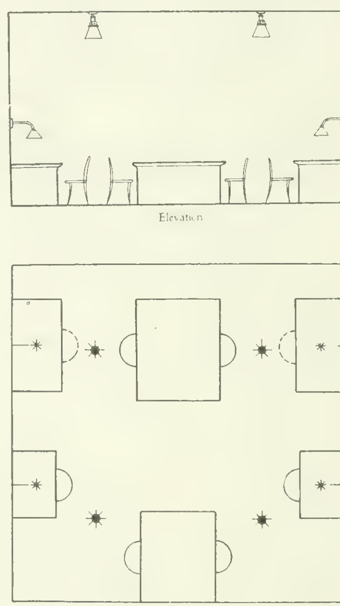


FIG. 2.

Second, the problem of maintaining a clean ceiling as a reflecting surface as well as clean inverted reflectors on the lamps appeared too great to admit of this system of lighting. In this scheme, however, the energy consumption was favorable and all eye strain practically removed. While tests of this system of illumination did not show it to be satisfactory for the conditions of this particular office, it is not to be inferred that it is unsuitable for office lighting where the conditions may be different.

Another step towards the betterment of the lighting conditions, and the plan finally adopted, consisted in the arrangement of nine forty-watt tungsten lamps with suitable reflectors as shown in Fig. 3. The four individual desk lamps were then removed with the approval of those who had been accustomed to their use. This result was obtained by spacing the edge rows of lamps two feet eight inches from the wall, the light being of satisfactory intensity for all wall desks and presenting a uniform distribution over the entire working plane of the room. The larger number of units used per-

mitted each one to be sufficiently small so that eye strain was entirely removed.

In the original system where one large light unit was used at the center of the ceiling, together with four auxiliary desk lamps as shown in Fig. 1, the energy consumption in this office was 750 watts, equivalent to 1.88 watts per square foot of floor space. In the case of the four tungsten lamps overhead with the four desk lamps still in use, as shown in Fig. 2, the energy consumption was 624 watts, equivalent to 1.56 watts per square foot of floor space. The arrangement of nine forty-watt tungsten lamps as indicated in Fig. 3 involved an energy consumption of 360 watts, equivalent to 0.9 watts per square foot of floor space.

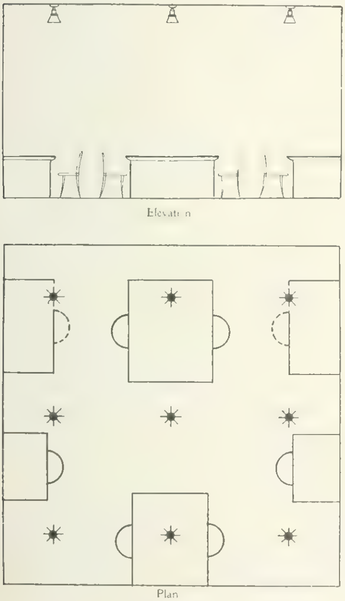


FIG. 3.

For the system as originally installed with all of the general light coming from the center of the ceiling, together with four desk lamps, the total annual operating expense, including interest, depreciation, maintenance (or lamp renewals) and energy, was found to be $28.38, assuming energy at one cent per kilowatt-hour; or $88.40 at five cents per kilowatt-hour; or $163.40 at ten cents per kilowatt-hour. These values assume six hours service per day. With the four overhead units and four desk lamps the total annual operating expense was found to be 17 percent less than that of the original scheme, while with the final arrangement of nine overhead lamps without the use of individual desk lamps, the total annual operating expense was found to be 40 percent less than that of the lighting installation as originally found.

The average installation cost of these three systems, including lamps, reflectors and wiring complete, was $30.00, no one system varying from this average installation cost by more than ten percent.

CONCLUSIONS

These trials and numerous other experiments in offices of various sizes and heights extending over a considerable length of time

have led to the formation of a number of rules which can be applied in the satisfactory illumination of offices. In general, however, each office to be lighted should be given separate attention in the application of simple illumination principles, as in the choice of size of lamps and type of reflector. The attempt to apply a set rule for all cases without due care and study will often result in conditions far from satisfactory.

The following may be considered as general specifications for office lighting, based on the experiments as outlined above:—

1—Small offices occupied by one man or by one man and an asistant should be treated as special cases. Usually one main light unit mounted high over the desk will be satisfactory.

2—Square offices up to say fourteen feet on a side and occupied by more than two persons, require a general overhead illumination of sufficient intensity to eliminate the necessity for individual desk lamps. Up to this limit four units arranged as indicated in Fig. 2 should be used, with the edge lamps about three feet from the wall to take care of the desks along the wall.

3—Square offices from about fourteen to twenty-two feet on a side should be equipped with nine units arranged as indicated in Fig. 3, edge lamps to be about three feet from the wall.

4—Square offices from about twenty-two to thirty feet on a side may advantageously be equipped with sixteen units arranged symmetrically as in the foregoing cases, the edge lamps to be about three feet from the wall.

In general all lamps should be mounted at or near the ceiling unless the ceiling are excessively high. Reflectors should be selected that are as concentrating as is consistent with uniformity of distribution, provided reflecting efficiency is not sacrificed by such choice. Where the office is rectangular the floor space may be divided into elementary squares and the above rules applied. Table I will be useful in laying out the illumination of both square and rectangular offices. The values given indicate only the number of rows of lamps and the number of lamps per row required for offices of various sizes in order to fulfill all the requirements for satisfactory illumination as stated above. This Table applies to offices having rather low ceiling heights up to about twelve feet. The size of the lamps involves the question of intensity. Having determined the number of units necessary for satisfactory lighting, the size of the unit should then be so chosen that the given number of lamps will

furnish the proper intensity on the working plane. The choice of a reflector depends on the spacing between lamps and the height of the lamps above the desk surface, while the reflecting efficiency will largely influence the resulting light intensity on the working plane. With the various sizes of metal filament lamps now available and the number of excellent reflectors on the market, it will always be possible to select a combination of lamp and reflector which will result in a maximum of satisfaction for general office conditions. The choice of lamps and reflectors should be based upon the illumination curves and other data in order that the light may be efficiently directed and uniformly distributed.

As an illustration, assume an office of 15 by 35 feet floor space. From Table I it will be seen that three rows of lamps with five lamps per row are required to furnish illumination fulfilling all the

TABLE I.

Dimension of office	Number of lamp rows
0 to 10 feet	One lamp at center
10 to 14 "	2
14 to 22 "	3
22 to 30 "	4
30 to 38 "	5
38 to 46 "	6
46 to 54 "	7

requirements as originally stated. The general rule to be followed in spacing of lamps is to space all "edge" lamps about three feet from the wall and so arrange the remaining lamps as to be equally distant from each other.

Where the ceiling height is such that the lamps may be mounted higher than about twelve feet, they are fairly out of the range of vision, and eye strain, due to rays of excessive brightness entering the eye from the light source, is no longer a controlling factor. In such a case it will often be found advisable to modify the Table so that smaller numbers of lamps, than indicated, of larger size may be used for a given floor space. This represents a somewhat lower first cost in initial installation work, and with care may be made to meet all the requirements of good office illumination.

The arrangement of the lamps above indicated as the outcome of the tests described, applies specifically to the particular require-

ments already outlined in which the lamps are to be arranged so as to give satisfactory illumination whatever be the arrangement of the desks. This condition has led to the placing of lamps nearer the side walls than would otherwise be desirable. Furthermore, in many cases a somewhat wider spacing of lamps would be satisfactory, but the limits given in Table I were chosen in order to secure primarily an excellent uniformity of light on the tops of desks.

One point of interest in connection with the tests is that the final arrangement was the outcome of experience rather than predetermination. It was anticipated that four lamps would give a proper and uniform distribution. When this arrangement proved unsatisfactory, nine lamps were installed with the advantageous results which have been pointed out.

The two arrangements, one of four lamps and one of nine lamps, were in service simultaneously and either one could be connected to the circutit. On one occasion, after the nine lamps had been in service for some time, the four lamps were substituted. There was an urgent call for a change to the other arrangement because it was so much more satisfactory.

THREE-PHASE RAILWAYS IN EUROPE

RUDOLFH E. HELLMUND

WHILE in this country the American Westinghouse Company has been a pioneer in the development of the single-phase railway system and has achieved remarkable results in this direction, the Italian Westinghouse Company has been engaged in bringing the three-phase system to a high degree of perfection. At first sight it may appear strange that these two companies should have followed so widely different lines of development, but the difference is only the natural consequence of the difference in the conditions for which the two companies were called upon to furnish equipments. In this country, for example, the requirements of such roads as the New York, New Haven & Hartford Railroad from New York to Stamford, and its contemplated extension, undoubtedly governed the development of the single-phase system to a very large extent. The one condition, in this case, that the locomotives must operate both by alternating and direct current, was sufficient to make the use of three-phase power impossible. But even without this, the conditions of this road are such that the single-phase system is much more suitable from the standpoint of successful and economical operation. There are numerous reasons for this of which only a few will be mentioned.

On account of the high speeds of the trains, as well as on account of the very numerous crossings and switches in the terminals, the double overhead contruction required for three-phase operation would have led to great complications and high cost. Moreover, the frequent stops of the local trains, in consequence of which the starting periods form a very large percentage of the total, naturally call for some system which, like the single-phase system, allows of economical starting. Also the flexibility in the speeds attained with the single-phase system is of great importance for operating conditions varying as widely as on this road.

In contradistinction to this, most of the Italian and Swiss railways which have been electrified up to the present time are operated at moderate speeds, and the crossings and switches at the stations are not exceptionally numerous. Thus the overhead construction with two wires (the rails serving as the third conductor of the circuit) does not lead to serious difficulties. On account of the lower speeds, the starting conditions are such that the starting losses, which are inherent with the three-phase system, are not of great importance. On the other hand, most of the roads are for heavy grade work, for which the three-phase locomotoves are well adapted, as they are somewhat cheaper than single-phase locomotives and

permit regeneration of power. These and several other reasons naturally led to the development and the adoption of the three-phase system which, under the conditions indicated, has given excellent results.

Since the three-phase electrification of the Cascade tunnel has attracted considerable attention in this country, the writer believes that a description of a few features of the European three-phase roads which attracted his attention during a recent inspection may be of interest. A complete description would be out of place since numerous articles, dealing with most of the essential features, have already been published.

The more important three-phase roads in Europe are the following:—

The Valtellina road along the eastern shore of Lake Como.

A recent extension of this line towards the South.

The Giovi road forming part of the line between Genoa and Milan.

The Savona-San Guiseppe road forming part of the line between Savona and Turin.

The Simplon Tunnel electrification.

THE VALTELLINA ROAD

This road has been operated electrically for a number of years and most of the apparatus, while it has been giving very good satisisfaction, may now be considered of an obsolete type, and will be considered very briefly.

The overhead construction is similar to that of direct-current lines and consequently is rather light for such heavy service. Outside of the tunnels the contact wires are suspended by cross-wires, a separate cross-wire being used for the trolley wire of each phase. Inside of the tunnels the contact wires are directly supported by the insulators. The lack of some means of providng for elasticity of the supports causes the trolley to jump when passing the supports at high speed and, in consequenece, rather strong arcing may be observed in the tunnels; this, however, has led to no difficulties. In fact, the wear of the cylindrical trolleys, which are being used on the Valtellina locomotives, is very slight, and, in spite of the arcing, the trolleys do not have to be renewed nearly as often as the sliding contact pieces used on other roads having equally severe service, as for instance in the case of the Simplon tunnel locomotives.

These favorable results obtained on the Valtellina road may be partly due to the fact that a rolling contact naturally has less mechanical wear than a sliding one. Moreover, the current passes through any point of the rolling contact only momentarily and the heating effect of the arc upon any part of the surface is of too short duration to cause a melting of material to as large an extent as in the case of sliding contacts.

Some of the passenger trains on the Valtellina road are operated by motor cars, while other passenger trains and freight trains are hauled by locomotives. The car equipments are old and of little present interest. The locomotive equipments are of several types. In the earlier type,* there are two twin motors, each motor set con-

FIG. I—VIEW OF SECTION OF NEW EXTENSION OF VALTELLINA SYSTEM, SHOWING TWO NEW TYPES OF POLYPHASE HIGH-TENSION CATENARY OVERHEAD CONSTRUCTION INSTALLED FOR SERVICE TEST

sisting of two motors mounted side by side, connected to the same shaft, and arranged for cascade operation. These are also of rather old design. In the later type of locomotive,* the equipment comprises two separate motors connected to the drivers by side rods. One of the motors is wound for eight poles and the other for twelve poles. For the lowest speed the motors are connected in cascade; for the intermediate speed the twelve-pole motor is used, and for the highest speed the eight-pole motor is used. At their full speeds the motors have one-hour ratings of about 1 100 and 1 500 hp respec-

*See article by Mr. Specht on "Multi-Speed Drive by Induction Motors" in the JOURNAL for December, 1909, p. 737.

tively. The control system of the locomotives is pneumatically operated. The power stations of the road are driven by waterpower.

NEW EXTENSION OF THE VALTELLINA ROAD

The new extension of the Valtellina road will be operated with the same locomotives and motor cars as the old part of this road. The new part of the line is however of some interest on account of its overhead construction. As this southern extension is a double track road, the Italian government has decided to try two new systems of overhead construction on the respective tracks. One of the systems has been designed and is being installed by the Italian Westinghouse Company, the other one by the Ganz Company, Budapest.

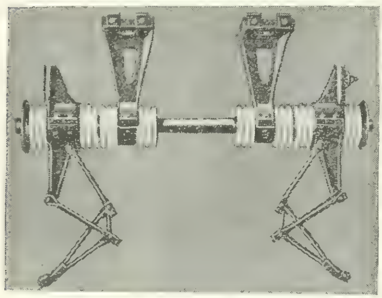


FIG. 2—DETAILS OF INSULATING HANGER USED IN THE TYPE OF CATENARY CONSTRUCTION SHOWN IN FIG. 1

These devices are used only at pole supports.

The Westinghouse system is a single catenary system. On tangents the poles are about 150 feet apart. Insulated cast iron parts on the cross-arms support the steel cables as shown to the left in Fig. 1, the Ganz system being on the right. The steel cables in turn support the two trolley wires by means of vertical straps. In order to prevent lateral motion of the trolley wires especially on curves, and at the same time allow them to move vertically when a trolley passes, a very ingenious lever system attached to each cross-arm has been devised, as shown in detail in Fig. 2. The levers are made of gas pipe and may be produced at comparatively low cost. Fig. 3 shows the manner in which the construction is modified, in the Westinghouse system, at cross-overs. This system is by no means as complicated as might be anticipated, in spite of the combination of two trolley wires with the catenary method of support.

The new Ganz system of overhead construction on the Valtellina extension consists, as with the Westinghouse system, of structural steel poles with cross-arms. Each arm supports, on insulators, two small wrought iron rectangular frames, one at each side of the arm, each of the frames serving by means of cross-wires to support a vertical member. The upper end of this member supports the steel cable and the lower end the trolley wire. The cross-wires allow for

a certain up and down movement of the system at the cross-arms, but it is doubtful if this will be sufficient to prevent sparking. The connections between the cable and the trolley wire are flexible.

THE GIOVI ROAD

The main line between Genoa and Milan has to cross the high mountain range of the Apennines. Going north from Genoa up to the summit of the range the road consists of two parallel lines. The line which is being used chiefly for freight has very heavy grades, and its operation with steam has led to great difficulties on account of the consequent speed limitations. To increase the capacity of the line, which is one of the most important in Italy, with steam operation would have been very difficult, because the nature of the territory makes the building of additional tracks next to impossible.

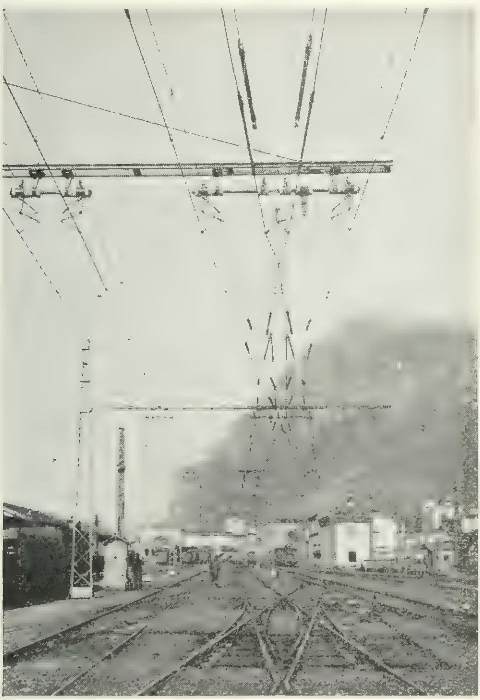


FIG. 3—HIGH-TENSION CATENARY OVERHEAD CONSTRUCTION EMPLOYING THE TYPE OF HANGER SHOWN IN FIG. 2 AS MODIFIED AT CROSS-OVERS Valtellina system.

The Italian government, encouraged by the good results obtained with the Valtellina road, decided, therefore, to electrify the old Giovi line, using three-phase current at a frequency of 15 cycles and a potential of 3 000 volts on the contact wire. Water power was not available since all rivers on the south side of the mountain range contain water for only certain periods during the year. A steam turbine power station was, therefore, erected in Genoa. The reason for locating the main station at one end of the line instead of at the middle was that the local conditions at this point were more favorable. The harbor of Genoa provides excellent coal transportation fa-

cilities. Fresh water for the boilers is accumulated from the rivers during the rainy periods and stored in large concrete reservoirs built underneath the power station. The station contains at present two 15 cycle turbo-generator units, each of 5 500 k.v.a. capacity. The generators are of the laminated field type with forced ventilation. The steam turbines are of the Westinghouse-Parsons type.

One feature in which the power plants for three-phase railway systems differ from those of other three-phase systems arises from the fact that provision must be made for the possibility that power regenerated by the locomotives going down grade may exceed the

FIG. 4—DETAIL VIEW OF GIOVI LOCOMOTIVE

Showing accessibility of secondary collector rings of motor.

power consumed by the other locomotives operating on the road at the same time. This is arranged for in a very ingenious way in the Giovi station. The bus-bars are connected to a series of water basins, which are arranged in steps at different heights. The higher basins are provided with valves by means of which the water may be allowed to flow from the upper basins into the lower ones, thereby establishing a shunt circuit for the bus-bar current, the conductivity of which can easily be varied by control of the volume of the water stream. The valves are opened and closed by means of small motors whose operation is controlled by the steam turbine governors. Thus, in case current is pumped back into the station from the line, the turbines will speed up and their governors will then start the valve motors, and thus open the valves until the

water stream is sufficient to dissipate the current from the line.

Power is transmitted to a number of sub-stations located along the road, each sub-station containing four single-phase transformers, one a reserve unit, the necessary automatic switches for disconnecting certain sections of the lines, and small choke coils connected in the trolley circuits.

By far the most interesting feature of the Giovi electrification is the type of locomotive used.† Two motors, connected to each other and to the drivers by a Scotch yoke and side rods, are used on each locomotive.

The new locomotives* are built for freight service and have a normal operating speed of 28 miles per hour. The design provides also for a second operating speed of 14 miles per hour, obtained by connecting the motors in cascade. This lower speed, however, is intended to be used only for switching purposes or similar service. It may also be used for regenerating power while the train is running down grade when a speed higher than 14 miles per hour is not safe. However, in considering the capacity of this locomotive, the higher speed should be taken as its normal operating speed.

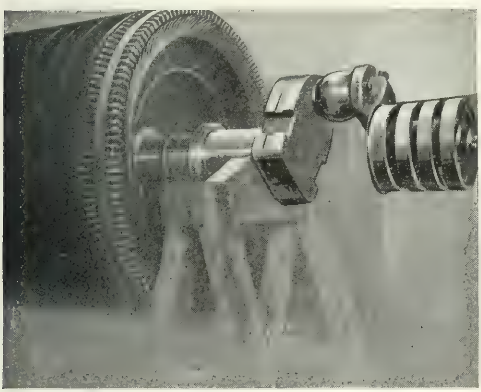


FIG. 5—DETAILS OF CRANK SHAFT AND COLLECTOR RINGS, AND ROTOR OF MOTOR
Giovi locomotive.

The interior of the locomotive does not appear at all complicated, although it is not quite as simple as the later Simplon locomotives. In the Giovi locomotives such apparatus as is apt to require little or no care is located within the end hoods extending from both ends of the cab. Other pieces of apparatus which require more frequent inspection are located at the middle of the cab. This arrangement has the advantage that the cab can be provided with windows all around.

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†These locomotives have been described in an article by Mr. K. von Kando, in *Zeitschrift des Vereines deutscher Ingenieure* for 1909, p. 1 249.

*A general view of this locomotive is given in the article by Mr. H. C. Specht, previously referred to, in the JOURNAL for December, 1909, p. 738.

There are some noteworthy points in connection with the government specifications for these locomotives which are extremely severe, although they have actually been met during the witness tests. For example, "The locomotive weight shall not be more than 60 tons, but the mechanical construction must be such that this weight may be increased to 75 tons by ballast. These locomotives must be able to meet for 20 hours the following test service conditions:— They must be able to handle a train of 380 tons trailing load, i. e., independent of the weight of the locomotive, at a speed of 28 miles per hour, from Pontedecimo to Busalla (a distance of 6.5 miles with an average grade of 2.7 percent, a maximum grade of 3.5 percent,

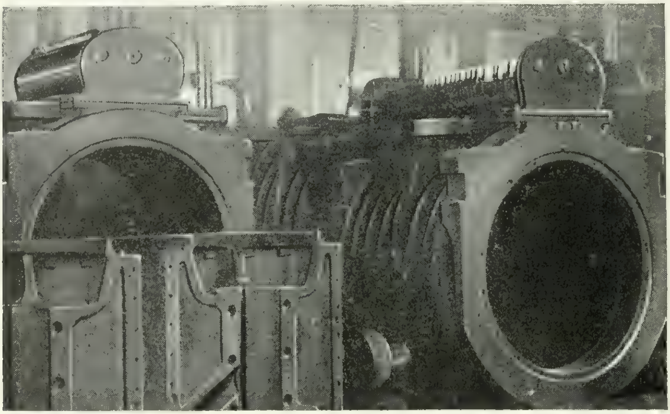


FIG. 6—DETAILS OF STATOR OF MOTOR SHOWING PRIMARY INTERRUPTING AND REVERSING SWITCH MOUNTED ON THE FRAME AND THUS FORMING AN INTEGRAL PART OF THE MOTOR
Giovi locomotive.

and a minimum radius of 1 200 feet), the return trip being made without stop-overs at a speed of 14 miles per hour and with the locomotive connected for regenerating power. The time allowed for one round trip is 140 minutes. After 20 hours of service such as that noted above, one round trip is to be made without forced ventilation of the motors, during which the temperature rise of the motors, (determined by the method of resistance measurements) must not exceed 75 degrees C. The one-hour motor rating for the same temperature rise is to be 720 hp per motor corresponding to a locomotive pull at the wheel circumference of 19 500 lbs." Both of these specified performance conditions have actually been exceeded by the motors.

The following conditions are specified for starting:—"The fric-

tion weight under most favorable conditions must be such that a train of 380 tons trailing load can be accelerated to 28 miles per hour by two locomotives, one pushing and one pulling, on a grade of 3.5 percent and a curve of not more than 1 200 feet radius, in less than 200 seconds. One locomotive must be capable of accelerating a train of 400 tons trailing load to a speed of 14 miles per hour on a grade of 0.3 percent and a curve of 540 feet radius or less, 30 times in one hour." This is an accomplishment which is quite noteworthy. especially in view of the fact that three-phase locomotives have the reputation of being ill adapted for frequent starting. The maximum starting torque of the motors is such that even with an increase of locomotive weight to 75 tons, it is possible to slip the wheels.

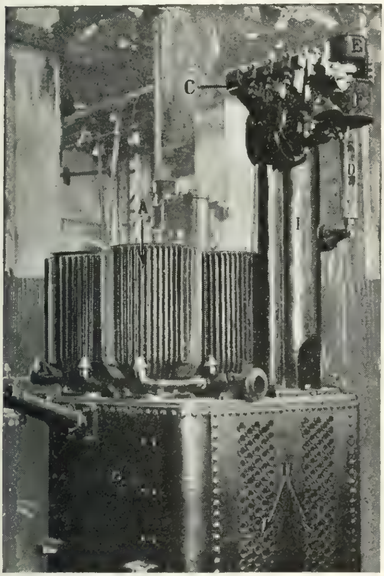


FIG. 7—THREE-PHASE WATER RHEOSTAT FOR CONTROL OF SECONDARY CURRENT OF MOTORS

A — Electrode receptacles. *B* — Air-cooled reservoir containing the electrolyte. *C*—Switch for automatically short-circuiting the rheostat when the electrolyte completely surrounds the electrodes. *D*—Dash pot connected with plunger of solenoids *E* and *F*. *G*—Air pressure system for increasing radiating power of electrode receptacles. *H*—Air cooling ducts in tank. *I*—Pedestal supporting the switch and control mechanism.

The motors have partially closed slots in both members and while, from the standpoint of American practice, this would probably be considered as a disadvantage with regard to repairs, etc., the Italian engineers contend that, with the windings employed and under the conditions given, the partially closed slot is an advantage and should always be used in similar cases. Their argument is that a concentric winding with a few heavy conductors may easily be wound with closed slots and that, after the motors are wound, the winding is better protected by the overhanging tooth tips than it would be by the fiber wedges in the case of open slots.

The arrangement of the slip rings outside of the crank-pin is frequently considered to be a risky form of construction, but it is so well developed in the Giovi locomotives that it may be considered

to be entirely safe. Moreover, the space ordinarily taken by the rings can be used to great advantage in increasing the length of the iron core. An important point is the accessibility of the rings when located on the outside, as is obvious by reference to Fig 4. The arrangement of the collector rings in connection with the crank, and details of the rotor are also clearly shown in Fig. 5.

The primary winding is completely enclosed and is surrounded by an insulating compound. This interferes, to a large extent, with the ventilation of the motor, but gives an exceedingly well protected winding and has given very good results on the Valtellina locomotives, which are constructed in the same manner.

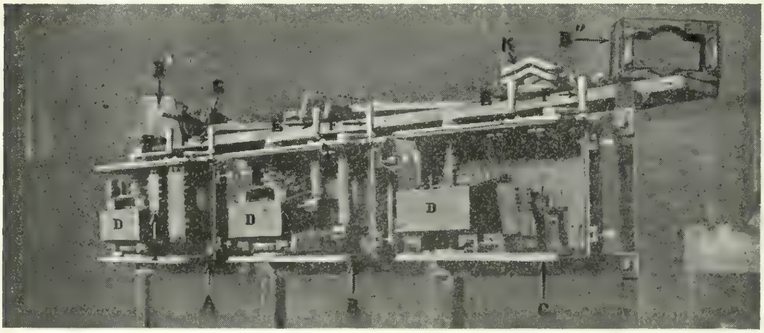


FIG. 8—DETAILS OF MASTER CONTROLLERS OF THE TYPE USED ON THE GIOVI LOCOMOTIVES

A, *B* and *C* represent three separate controllers being assembled in the shop. *D*, *D'*, *D''*—Laminated iron of induction regulator stator. *E*—Controller handle attached to armature of induction regulator, the position of which determines the maximum current that may be taken by the motors. *F*—Controller handle which governs the operation of the primary interrupting and reversing switch of the motors. With a given setting of the current regulator handle, and the handle *F* set for either of the two running speeds, forward or backward, the operation of the primary switch, the accelerating mechanism, and the water rheostat, Fig. 7, is entirely automatic. *G*—Armature of induction regulator. *H*—Collector rings of armature. *I*—Switch controlling the mechanism for raising and lowering bow trolley. *J*—Handle for operating *I*. *K*—Stator coils for induction regulator.

The motors have a capacity of nearly 1 000 hp on the basis of a one-hour rating, and 550 to 600 hp, continuous rating, both ratings being based on a temperature rise of 75 degrees C. as determined by resistance measurements. The heat tests for determining these ratings were made by running the locomotive continuously with a certain train, on a track giving a fairly uniform motor load in both directions between two stations which were chosen with this point

in view. The tests allow, therefore, for a comparatively large number of starts and correspond to actual working conditions.

Control System—The control system of these locomotives is, when judged from the wiring diagram, hardly any simpler than that of other locomotives, in fact, it may appear to be more complicated than that of some straight single-phase equipments judged from this point of view. It contains a number of excellent features, however, which are made possible partly through the use of three-phase power and partly due to good design, in which, as far as possible, such parts as have proven to be the cause of most of the trouble experienced in connection with other systems have been eliminated.

The starting resistances are of the water rheostat type and hence it was necessary to design the secondaries of the motors for low potential operation; this was also desirable in order to have low potential on the slip rings. The design of the control system involves a provision for connecting one of the stators for low potential when the motors are operated in cascade connection. The switch performing this operation of re-connecting one of the stators from high to low voltage is the only switch mechanism in the system which has a relatively large number of contacts carrying other than light currents. It may therefore be compared, in this respect, with either the auto-transformer tap switches of single-phase systems and polyphase systems with squirrel cage rotors, or with the resistance tap switches of systems using metallic starting resistances. In practical operation, however, it is far superior to these, since it is always operated without current. It is also superior to the latter since it may be operated by two relays; whereas, in the other cases, as many relays are required as there are taps, assuming, of course, the master switch type of control.

The wiring required in connection with the commutating switch is reduced to a minimum by mounting the switch directly on the motor and handling it as a unit therewith. This feature may be seen by reference to Fig. 6. The switch extends from below into the cab of the locomotive and may be readily inspected by removing the protecting cover.

Water Rheostat—The use of the rheostat should be considered as one of the main advantages of the control system, since by its use all metallic resistance parts are eliminated. Thus no contacts have to be operated under current, except the one which short-circuits the rheostat. This latter contact does not cause any difficulties, however, since it operates only when the voltage impressed on the

rheostat is about zero. A further advantage of the water rheostat is the fact that it does not increase the current by steps but allows of the finest possible regulation.

Each rheostat consists of a large boiler iron tank containing the electrolyte, smaller cylindrical receptacles containing the electrodes and a vertical column extension supporting the regulating mechanism. The larger water receptacle is mounted so as to extend below the cab, where it may be cooled by the air passing through the cooling tubes in the boiler iron tank. The electrode receptacles extend into the cab hoods, while the regulating mechanism extends into the cab proper; thus it may be conveniently inspected by removing the protecting cover. A detail view of a three-phase rheostat of this type is shown in Fig. 7. The position of a float within the tank *B*, controls the opening and closing of the short-circuiting switch *C*. The electrodes of the three phases are permanently suspended within their permanent receptacles *A*. The latter are connected to the tank in such a manner that when compressed air is introduced into it, under the control of the regulating mechanism *E, F, D,* the electrolyte is forced up to the required height around the electrodes.

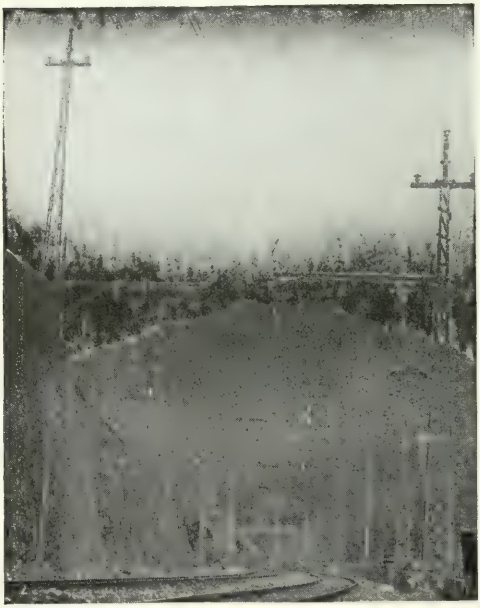


FIG. 9—DETAILS OF OVERHEAD CONSTRUCTION USED ON GIOVI ROAD

The type of bow support employed gives considerable flexibility in a vertical direction. Adjustments are readily made to suit the requirements of curves where banking of the track requires shifting of the wires and variations of their height.

Primary Switch—The only switch which is opened under current is the primary switch; but even for this switch conditions are much more favorable than for any of the current interrupting switches of other systems. The current interruption in the primary of wound secondary induction motors may be practically reduced to

the magnetizing current by inserting resistance into the secondary before breaking the primary current. For this reason it has been possible to use air switches on the Giovi locomotives which after an operation of one year were still in good working condition, although the contact parts had not been renewed or repaired during that time.

A good feature of the primary switch of the Giovi locomotive is that it serves both as an interrupting switch and a reversing switch as well, *without* requiring additional contacts for the reversing function. This is accomplished by simply rotating the movable contact parts through a certain angle in order to reverse the motor.

Multiple Control—The fact that each locomotive can be set for a certain maximum current, would make it quite possible to use locomotives in multiple without a special multiple control system, nevertheless such a control arrangement is provided. A special controller, arranged to allow for various operating conditions, is used in connection with this system. The multiple control system not only allows for the operation of locomotives of different wheel diameters in multiple with equal loading, but also allows for loading them differently with any desired ratio of load distribution. This is quite advantageous, because it is frequently desirable to keep the draw-bar pull of a pulling engine within certain limits and let the pushing engine take care of the larger part of the load.

Master Switch—The master switch is arranged for two levers. One of the levers has four definite positions corresponding to the two forward and two reverse speeds. The second lever regulates the current consumed by the motors. Every position of this lever determines positively a certain maximum current taken by the motors. When, at any time, the motor tends to take a current larger than that corresponding to a given lever position sufficient additional resistance is automatically inserted in the secondary to limit the current to the predetermined maximum value. This is accomplished as follows:—The operating lever of the master controller rotates the armature of a small induction regulator and thereby regulates its secondary potential. The induction regulator secondary is connected to one coil of a relay, this coil being counteracted by a second coil which is excited by means of a current transformer connected in the main motor circuit. Whenever the pull of the two relay coils is balanced, the armature will be in the middle position and the motor currents will remain unchanged. As soon as the motor current increases, the armature will be attracted by one coil and close a relay circuit which will increase the resistance in the second-

ary. If, on the other hand, the motor current decreases, the armature will be attracted by the other coil and close another circuit of the relay, thus causing the regulator to operate in such a way as to decrease the resistance in the secondary. Three master controllers, in various stages of assembling, are shown in Fig. 8. Each locomotive is equipped with two of these controllers connected in parallel, one at each end of the cab.

Current Collectors—The current is taken from the line by a bow trolley with long roller contacts of the same construction as used on the Valtellina line. It is also intended to use, in connection with the Giovi electrification, a number of bow trolleys of the Brown-Boveri type with sliding contacts, the general features of which are shown later in connection with the description of the Simplon locomotive.

Troubles and Repairs—There have been exceedingly few troubles experienced with the Giovi locomotives. As a preliminary service test, the first Giovi locomotive was placed in service on the Valtellina road the latter part of 1908 and thereafter was kept in operation as continuously as possible. When the writer was in Vado this locomotive was back for inspection. However, there were no changes or repairs to be made, except the renewal of such parts as bearings, etc., which are subject to wear and tear in any case.

Vibration and Noise—The locomotive is comparatively free from vibration and noises of any kind. The only noticeable noise is when the motors are started under a comparatively heavy load and the water does not rise uniformly in the respective steps of the rheostat. In this case a slight vibration is noticeable during a few seconds of the starting period.

Overhead Construction—The overhead construction is being built by the Italian Government from material furnished partly by the Italian Westinghouse Company and partly by the Brown-Boveri Company. Since it is not a catenary system, the distance between poles had to be made smaller than would otherwise have been chosen. Two parallel contact wires are used for each of the two overhead phases. These are supported in the manner shown in Fig. 9.

(To be continued.)

HIGH-TENSION CONCRETE SWITCHBOARD STRUCTURES

FROM THE STANDPOINT OF THE ERECTION ENGINEER

W. R. STINEMETZ

THE construction of concrete switchboard structures brings the erection engineer in contact with many problems peculiar to this class of work, both from the electrical standpoint and that of the contractor who is familiar with ordinary concrete work. The average erection engineer finds it difficult to build structures of this kind effectively and economically until he has become acquainted with the details of their construction through what is often trying experience; the average contractor, in turn, finds himself on unfamiliar ground when he attempts to handle concrete work requiring such close attention to detail dimensions and finished appearance.

The writer does not presume to tell how concrete structures should be built but, having been engaged in erection work and having thus come in contact with some of these phases of its development, proposes, in this article, to give the conclusions from his own experiments and observations with the thought that possibly some others may profit by his experience.

FORM WORK

Bearing in mind the fact that the carpentry work, both in building and setting up the forms, constitutes a large percentage of the expense of building concrete switchboard structures, anything which can be done to minimize the number of forms and make them easily handled and adjusted will materially decrease the total cost. Various methods have been employed in the building of concrete switchboard structures of the general type shown in Figs. 1 and 2, and opinions differ in regard to the best method of procedure. Although not entirely distinct as to details they may be outlined in two general classes:—

1—Some engineers prefer to make all the shelves and pilasters separately, casting a few at a time and using the same forms repeatedly. They then group these into the main wall as the work on the latter progresses. The knife switches and insulators may also be placed in the main wall as it is built up, pouring the concrete around them after they have been fixed in position. In this case

the height of each pouring is limited by the position of the apparatus thus inserted. When the shelves and pilasters are poured previous to the building of the structure, for insertion afterwards, difficulty is sometimes experienced in getting them lined up correctly and very often considerable chipping is necessary in order to make them fit properly in the structure. If the wall is carried to the bottom of each line of shelves, as shown in Fig. 3, and these are then placed,

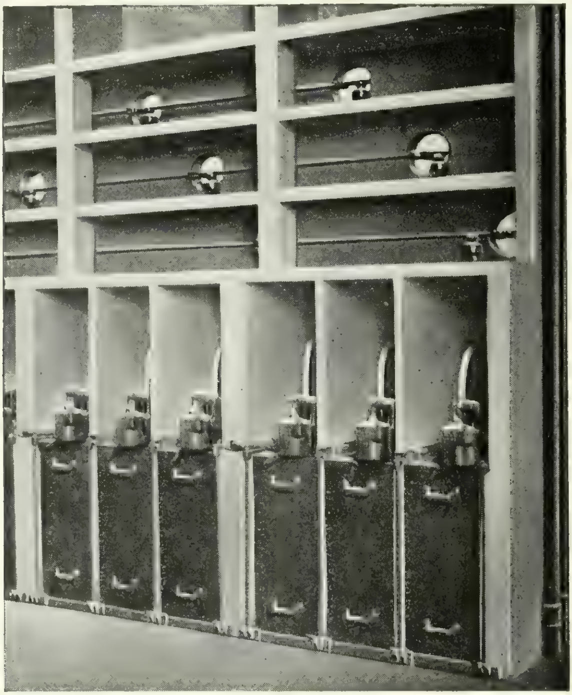


FIG. 1—FRONT VIEW OF SECTION OF A CONCRETE SWITCHBOARD STRUCTURE
Oil circuit breakers and bus-bars installed.

the pourings are limited by the height from one shelf to the next, and the form work is complicated in proportion. Cases may be cited where the rear barriers were cast in advance of the structure and a great deal of trouble and expense were experienced in placing and fitting them correctly in the structure.

2—The writer's experience would indicate that to cast all parts in place when possible is not only cheaper as regards both labor and forms but that a much more substantial and accurate structure is obtained. In some cases, of course, isolated or small barriers which

are easily handled may be cast separately with economy, but these are exceptions. This method might be applied to the extent of pouring each shelf at a separate pouring, giving six operations, as indicated in Fig. 3; however, in the work which is used as an example in the present description, the most effective method of procedure was found to be as follows:—The entire structure is poured in place, such details being added to the forms as are required to provide for the openings for the various apparatus in the main wall, this apparatus being inserted after the completion of the concrete work. The front of the main wall is carried up straight with recesses formed therein for the shelving which is poured afterwards. This makes the form work for the front of the structure a simple matter.

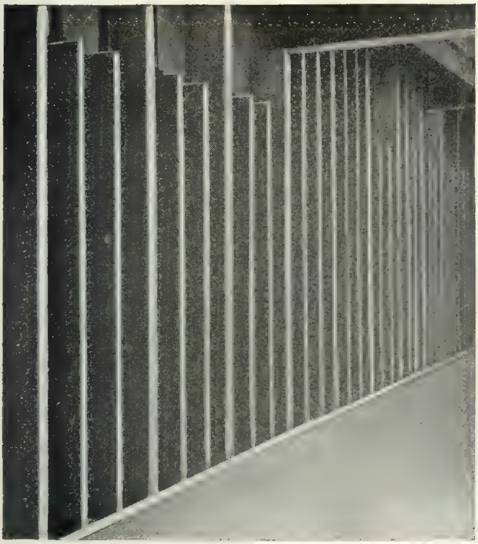


FIG. 2—REAR OF CONCRETE SWITCHBOARD STRUCTURE SHOWING VERTICAL BARRIERS

View taken before installing wiring or apparatus.

In the present installation, with the forms designed to complete the structure in four pourings, *exclusive of the shelves,* the first pouring includes everything to the top of the oil circuit breakers; the second, to the top of the bottom busbar shelf; the third to the bottom of the fourth shelf, and the last, to the bottom of the finishing shelf on top of the structure. These pourings will vary from two and one-half to three feet in height, and for structures involving seven or eight switches, each of these sections would be made in one pouring. For longer structures these sections could be made in two pourings using the same forms for both.

The rear or barrier section of the structure is practically uniform from bottom to top. Fig. 4 shows the design of these forms together with the method of mounting them. They are made of seven-eighth inch Georgia pine flooring two and one-half inches wide, nailed to one and one-fourth by three inch battens 36 inches

long. The tongue and groove is fitted loose so as to allow for swelling when wet. Experience has shown that two and one-half inch boards are much less liable to warp than wider ones. If cheap lumber or wide boards are used, they will warp so as to be useless after the first pouring. These forms are practically water-tight and present a smooth surface. The battens on the rear or main wall forms are so placed that when the adjacent or barrier sides are butted up against them, the barriers become self-aligned. The small wooden spacers shown in the barrier section are inserted to maintain the proper width of barrier. These spacers are taken out as the concrete is filled in. The edge of the barrier is formed by a simple

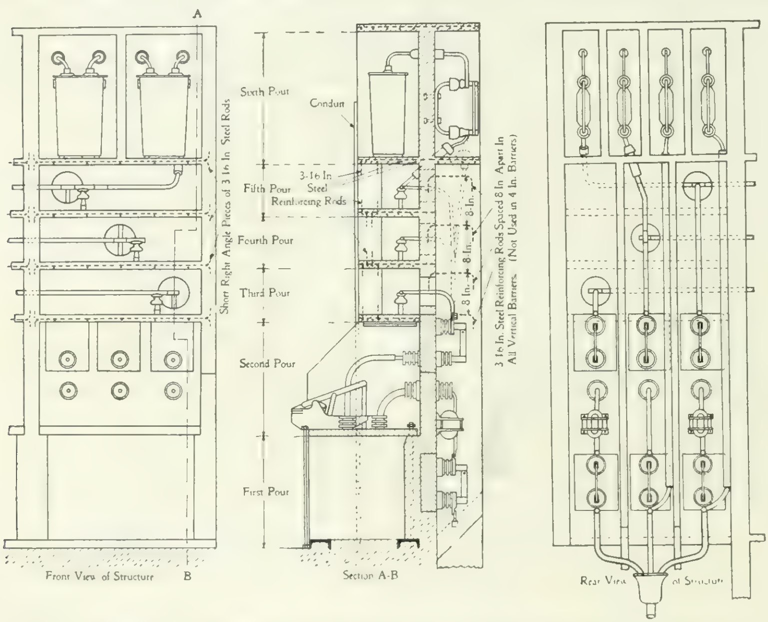


FIG. 3—FRONT AND REAR ELEVATION AND CROSS-SECTION OF PORTION OF SWITCHBOARD STRUCTURE SHOWING STEPS IN POURING

strip, one and one-half by two inches or four inches, according to the thickness desired. This is clamped between the side forms by three bolts as shown in Fig. 5. Thus, when the bolts are drawn up, the proper spacing is obtained at this end. To remove these forms after the pouring is made, the bolts are loosened, when the strip will drop out and the removal of one side form releases the other two without danger of breaking the green barriers. Care should be taken to set up the forms in such a way as to avoid the possibility of their becoming wedged between parallel walls through

swelling of the wood, as the concrete is liable to be cracked in prying them out. The strip shown fastened to the top edges of the barriers indicates the method of spacing at the front. For the first pouring a strip is placed along the bottom edge also. But after the first pouring the forms are moved up, and the bottom of the form is bolted to the top of the previous pouring, and the lower strip is no longer necessary. A brace is also necessary at the top and bottom of each barrier, as shown in Fig. 6, to prevent the concrete from forcing the forms out of plumb.

The front of this structure changes in design for each pouring and therefore changes in the form work are necessary, but by following the method of omitting the shelves temporarily, these are much simplified. For the first pouring forms are used similar in design to those of the rear barriers, as just described, except that,

FIG. 4—PART OF FORMS USED IN POURING REAR BARRIERS

as these are only used once, the bolts are omitted, and the side forms are made to come flush with the front of the switches. The second pouring consists of a straight wall with partition barriers projecting between each oil switch group. Fig. 7 shows the forms in place, each section being of the same width as one oil switch group. These forms are also used to form the front of the oil switch cells in the first pouring, and afterwards, by setting them end to end, to carry the front clear up as a straight wall, thus saving considerable lumber.

The method of bracing the fronts is similar to that for the rear section, using boards extending to a convenient wall; in most cases these structures are so located that this method is feasible and easily accomplished. If the structure is built in an open room, it will be

necessary to erect a substantial framework around it to brace to, or to brace diagonally from the floor.

SHELVING

The method of forming the front shelves is shown in Fig. 8, which also illustrates the manner of locating the various switches and openings in the main wall. Open boxes of the proper size, braced diagonally to hold them true, form the openings for the knife switches. For the small insulator openings sections of four-inch pipe are used. For the eight-inch holes wooden rollers have been found to be satisfactory. They are cut into four-inch lengths and then given a slight taper; a hole is bored through the center of each to hold it in its proper position by bolting through the side

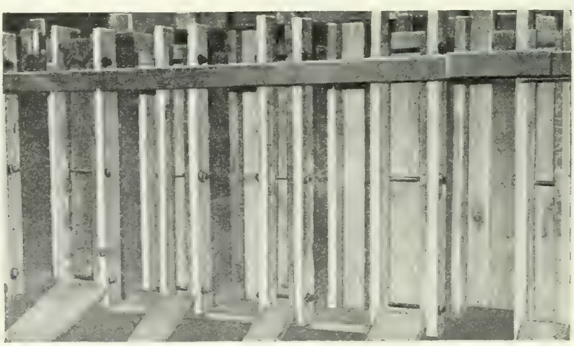


FIG. 5—REAR BARRIER FORMS IN PLACE, SHOWING BOLTS FOR CLAMPING THEM

Pour No. *1* (see Fig. 3).

wall forms, and a slot is sawed from the circumference to this center hole. This slot allows the core to shrink as it dries and thus to be easily removed from the concrete. An iron pipe of this diameter wedges so tightly in the concrete that it is impossible to drive it out without injury to the main wall. These various forms also act as spacers for the main wall side forms.

When the structure has been carried up to the fourth shelf which completes the third pouring, it then becomes necessary to build the shelves, as the four-inch barrier walls between the shunt transformers rest on these shelves, as shown in Fig. 3. The shelves are made in a single pouring for each row. The bottom row rests on the partition walls of the oil switches and it is not necessary to support them in the main wall. The other three shelves are supported in the

main wall while they rest on pilasters in front. The recesses in the main wall for these shelves are made by nailing strips on the front form when the main wall is poured. Fig. 8 shows two of the shelves in place in the wall with the forms still in place, and above them one of the recesses with the strip removed. The bottom shelf, together with the pilaster to support the next shelf, constitutes the first pouring. For these forms, simply heavy boards one and seven-eighths inch thick are used instead of the flooring. These boards are supported at either end of each switch section or pilaster. A strip nailed along the front edge extending two inches above the top of these boards gives the thickness of the shelf. The boxes for the

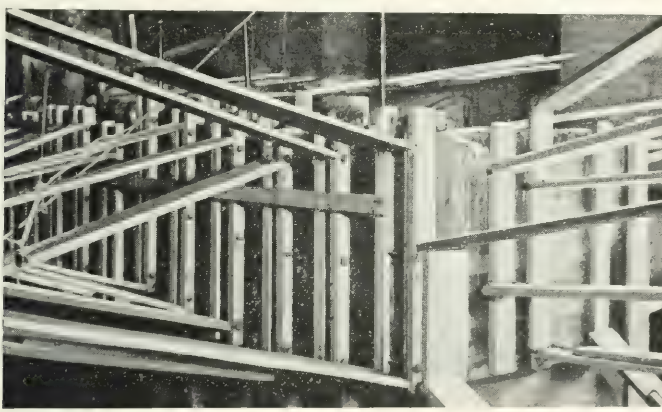


FIG. 6—REAR BARRIER FORMS BRACED AND READY FOR POURING CONCRETE

Pour No. 2 (see Fig. 7).

pilasters are made with one side fastened by screws. By removing this side these forms can be drawn away and used for the next row of pilasters. The forms for the respective shelves, however, are left on so as to take the weight of the shelves above and also as a protection from injury by workmen. In this way a row of shelves can be poured every day, if the forms have been prepared beforehand; whereas, if the forms for each row are taken off, considerable time will be lost in waiting for each set to dry out sufficiently to stand the strain of the next pouring. This method gives an accurate and straight line of solid shelving and pilasters which are tied to the main structure as one mass irrespective of any defects or irregularities which may have been made in forming the recesses for them in the main wall.

A simple method of making an adjustable form for isolated

shelves or barriers is illustrated in Fig. 9. This form consists simply of four pieces of two-by-two inch strips the ends of which are cut to the width of the shelves desired and slotted into the sides as shown. A clamp at each end is all that it necessary to hold them rigid. The length can be varied by cutting new slots, and the width by sawing off the end strips. Care should be taken that these forms rest on a perfectly flat surface, otherwise the weight of the concrete will warp them and give a correspondingly warped shelf.

REINFORCEMENT

The question of reinforcement for these structures seems to be one of individual judgment, a good deal depending upon the character of the ingredients to be used, the style of structure to be built,

FIG. 7—FRONT WALL, OIL CIRCUIT BREAKER CELLS, AND FORMS ARRANGED FOR POURING BARRIERS BETWEEN SWITCH COMPARTMENTS
Pour No. 2

and the thickness and other dimensions of the sections. Occasionally structures are built without any reinforcement; some use expanded metal which comes in sheets, while others prefer steel rods. Trouble is sometimes experienced in using expanded metal where the concrete is poured in long barriers by means of forms, as it is difficult to keep it in the middle of the barrier and its effectiveness in reinforcing against side strains is somewhat doubtful.

In the writer's experience with these structures the best results have been obtained by adopting the round steel rod. In some cases 5/16-inch rod is used; in others, a 1/4-inch size is ample. This is more easily adapted for insertion in the various parts of the structure where reinforcement is considered necessary. The lines on the shelf form shown in Fig. 9

indicate in general the proper spacing of the reinforcing rods for shelf work. Where the shelves are made in the structure in a continuous pouring the rods would extend the full length with the cross-rods reaching into the recesses of the main wall, as shown in Fig. 3. In the main wall, rods are always placed above and below any core forms that are inserted in the wall to provide for apparatus.

For the long vertical two-inch barriers at the rear of the structure three rods are used for the length, while the barriers are tied into the main wall every twelve inches by cross-rods hooked down

FIG. 8—FORMS FOR SHELVES, PILASTERS, AND DETAILS IN MAIN WALL

Conduits for the secondary wiring are shown partly imbedded. The recess into which the third shelf is to be grouted is shown with the cleat removed.

at each end. The reinforcement is always allowed to extend beyond the pouring so as to form a continuous tie for the next section.

CONCRETE

There are several combinations or mixtures used to make the concrete for these structures. Many are built of a mixture of sand and cement in the proportions of one part of cement to two and one-half of sand. In some cases a small gravel is added making a mixture of one, two and four or even one, three and six. In other cases granolithic stone is substituted for the gravel. Another mixture is made with cinders in the place of gravel or stone.

The sand and cement mixture undoubtedly makes a smooth pouring but it is probably weaker, more brittle, and less elastic than

any of the others. Barriers of this mixture are easily cracked and the edges are easily damaged. Then again they are difficult to drill without fracturing. The objection to the gravel and granolithic stone is the excessive weight and its greater impenetrability in case drilling is necessary. In a structure recently completed, it was necessary to drill about eight hundred holes for expansion and other bolts in erecting various apparatus on the structure, so that the item of drilling may be an important one. After experimenting with

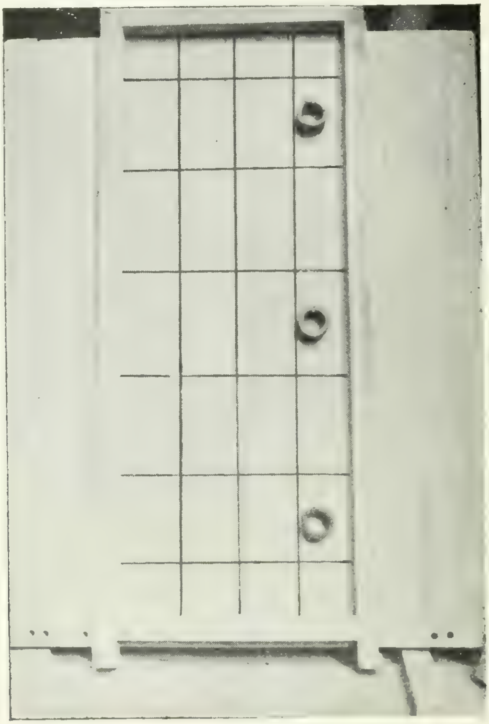


FIG. 9—DETAILS OF FORM SUITABLE FOR POURING SMALL OR ISOLATED SHELVES AND BARRIERS

The cross-lines represent the steel reinforcing rods and show method of strengthening at points where holes are required.

these different mixtures, the writer has come to the conclusion that the cinder mixture is the most satisfactory, when a sufficient supply of cinders of proper quality is available. They should be of a good grade, clean, hard and small, with no clinkers. When mixed in the proportions of one part of cement, two of sand and four of cinders, poured sloppy and puddled well, the surface, on

removal of the forms, will compare favorably with the sand and cement mixture. The cinder concrete forms a much lighter structure, which is strong, substantial and elastic; and which can be readily drilled without danger of fracture or cracking.

FINISH

There are two methods of finishing a structure of this kind. One is to go over the surface, as soon as the forms are removed, with a thin cement mortar of one part cement to one and one-half parts sand, rubbing the surface with a brick or wooden trowel to secure the desired smoothness. This is called a sand finish. The appearance of the finished structure is about the same as with sand and cement pouring.

FIG. 10—REAR VIEW OF SECTION OF COMPLETED STRUCTURE WITH SERIES TRANSFORMERS, SWITCHES AND WIRING INSTALLED

The other method is to face or plaster the entire structure after completion. In this case the concrete mixture need not be poured so wet and, aside from meeting the specified dimensions, less care need be taken as to the appearance of the rough pouring. In this case, the more air holes and cinder exposed, the better the surface for the facing to cling to. This operation requires expert work by an experienced plasterer and adds about 15 percent to the cost of the structure. Unless one is sure of the ability of the man engaged to apply the facing, it is better to take more care with the pourings and rub them up as the forms are taken off and while the concrete is still somewhat damp.

A wet mixture is necessary so that the concrete can easily be forced into the narrow spaces and around the cores in the forms. The top of the previous pouring is always covered with a layer of group before beginning the next pouring, as this makes a good binding between the two pourings. The time which each pouring should be allowed to set, before removing the forms and building up on the green work, varies with the conditions at hand. In building a structure recently in a dry, hot room the forms were removed

the day following the pouring. In open buildings or where the weather is damp a much longer time is required. A safe procedure is to allow the concrete to set 36 hours before removing the forms; it will then have another 24 hours exposure to the air while the forms are being cleaned and made ready for the next pouring.

In work such as here described for structures of from six to ten oil switch sections and with experienced laborers, the time between pouring will average at least five days, divided as follows:—two days to line up and brace the forms; one day to make the pouring; one day for the concrete to set; and one day to remove and clean the forms. The four rows of shelving can be poured in one week, as the forms and braces are not removed at the time. By this method it would, therefore, take about six weeks to complete a structure of from six to eight oil switch sections ready for wiring.

COST

The cost of concrete switchboard structures depends to a considerable extent on local conditions, the facilities for handling the

TABLE I.—APPROXIMATE DISTRIBUTION OF COSTS—CINDER CONCRETE SWITCHBOARD STRUCTURE.

	Percent.		Percent.
Lumber	5.6	Labor in making forms	10
Cinder	1.0	Labor in setting up forms	38
Sand	1.2	Labor in pouring forms	15
Cement	3.4	Labor in facing forms	16
Reinforcement rods	1.3	Labor in setting switches	7
Hardware and Miscel.	1.5		

material, and the experience of the men employed. Table I represents the itemized percentage of the total cost of building a cinder concrete structure, finished by facing, designed to accommodate 20 high-tension oil circuit breakers, the structure in question being 78 feet long and 12 feet high. The item "setting up forms" includes the labor used in placing and aligning the forms for a pouring, removing, cleaning, drying and soaping them after each pouring; also the labor of the carpenter in making the smaller detail forms for switches, etc., ready for the next pouring. The item "pouring forms" constitutes the actual cost of mixing and handling the concrete. The item "setting switches" includes the placing of the oil circuit breakers, knife switches, insulators, and all material which goes in the structure, but does not include such items as series transformers, nor the wiring.

STANDARDIZATION OF FORMS

There have been numerous suggestions of late as to the standardization of forms for use in connection with concrete switchboard construction. For example, it has been proposed that the design of the structure and apparatus be standardized as far as possible so as to minimize the number of different forms required, these forms being made of sheet iron so as to be transferred from place to place. There are some classes of concrete work where this is done, such as sewers, tunnels, standard walls, etc.; and it results in a great saving. But the form work for concrete electrical switchboard structures is so varied that it is necessary to have an experienced carpenter on hand from start to finish to take charge of the form work. The construction of the forms, their setting up and alignment, and the making of the various smaller detail forms during the intervals between pourings, all require care and experience. As a matter of fact, with a little repairing, a set of wooden forms has been made to serve for three structures, after which they were then discarded as worthless. A set of three iron forms for the back and two sides of each oil switch cell could be standardized and shipped from job to job, while the fronts which determine the thickness of the cell walls and are variable, could be supplied anew for each individual job. Such iron forms would last indefinitely. The feasibility of using standard forms is open to some question, both on account of the possible expense of shipping to and from a given job, and because of the possibility of interrupting the progress of the work due to difficulty in obtaining possession of them at the right time.

A standard type of vitrified clay bushing or a wooden form could well be supplied with the structural material for the four-inch and eight-inch holes, as forms for these holes are not always obtainable. Aside from the foregoing, the writer's experience would indicate that the adaptability and general ease of handling of wooden forms outweigh any results that might be obtained by extensive standardization. The main requisite for a good, cheap concrete structure is experience.

PARALLELING LARGE ALTERNATING-CURRENT SYSTEMS

P. M. LINCOLN

ORDINARILY the utilization of alternating-current power transmitted to a given locality is simplicity itself. It is only a matter of installing the necessary transformers and switchboards, making the connections and turning on the current. However, if it is desired to take a small part of the power required from the transmission lines of a large system, and supply the remainder from a local system already in operation, the problem becomes more involved. Moreover, the difficulty increases as the proportion of power to be taken from the transmission line decreases.

Suppose for instance, that there is a large hydro-electric, alternating-current transmission system supplying power to a surrounding district of considerable extent. Suppose further that there is a local alternating-current plant within the transmission company's district, whose capacity is, say, 20 percent of that of the first system and that the local plant wishes to secure a relatively small proportion of its total power from the transmission system to take care of an increasing demand for local power. At first glance it appears perfectly easy; all that seems to be necessary is to install a bank of transformers with their high-tension windings connected to the high-voltage transmission system and their low-tension windings to the lines of the local plant; or if the lines are of different frequency, a frequency changing set will have to be added to the transformer equipment. Naturally the transformers and other interconnecting apparatus would be selected of the proper capacity to carry the amount of power that the local plant wishes to purchase from the transmission company. Although such an equipment appears at first glance to be entirely sufficient, further analysis will show that it is quite inadequate.

When two synchronous systems are connected together by a transformer or by a motor-generator set consisting of synchronous units, the result is that both of the large systems are, for all practical purposes, operating in parallel. In order to secure the proper division of load between the various units in any alternating-current system it is necessary to have a drop in speed as the load comes on. The amount of this drop in speed varies. For water power plants the decrease from no-load to full-load is usually about four percent.

It follows, therefore, that as the load changes upon the various units, the average speed of these units also changes to a slight extent. For instance, if the load on a transmission system increases from an average of one-half load upon the respective units in parallel to full-load, there will be a decrease in speed (and, therefore, in frequency) of about two percent. Now consider that the two systems mentioned above are connected together and that there is a change in the load on the whole transmission system such that the average load upon the respective units is decreased from full-load to one-half load. This fluctuation in load per generating unit may come either as a result of connecting in one or more additional units or from an actual change in the load on the system. No matter how the load change occurs, the result, as indicated above, will be an increase of two percent in the frequency of the transmission system.

Suppose that while this is occurring on the transmission system there is no change in the loading or in the number of units in operation at the local plant. The latter will, therefore, tend to operate at exactly the same speed as before. However, with the proposed transformers or synchronous motor-generator set connecting the two systems, all of the generators in both stations will be held together to exact relative speeds; that is, there will have to be a change in the speed of the local generators. As a result of this condition, the generators in the local plant will automatically drop such an amount of their local load as will effect the required increase in speed, and this power must, of course, be supplied by the transmission system through the connecting link. Neglecting a possible slight decrease in the speed of the transmission system as a result of this transfer of load, the speed of the local generators will, in the case under consideration, be increased by two percent. If the local generating units also have an inherent speed variation of four percent from no-load to full-load, this two percent speed change will mean that the average load on the local plant must vary by an amount equal to 50 percent of the connected generator capacity in the local plant. Since all of this power must be carried by the connecting unit between the two systems, in addition to the load it was already carrying, it is obvious that a unit which has only a small proportion of the capacity of the local plant may be altogether too small to take care of such conditions, which may be continually changing with the variation in relative loads and number of units in service in the two systems.

In addition to the conditions of normal changes in load, there

will be a tendency for heavy loads to be exchanged through the connecting unit by such occurrences as short-circuits or other accidents upon either of the systems. Such accidents might tend to exchange much more power than the amount indicated above. On this account also it is impossible to expect successful operation with a relatively small connecting unit.

Furthermore, contracts for power between transmission companies and their customers ordinarily involve in some manner the maximum power delivered. With a synchronous unit interconnecting the two systems it will be practically impossible for the local company to have control over the amount of power which is taken from the transmission system. This result follows from a consideration of the data given above as follows:—

The local company evidently cannot control the frequency of the transmission system, which will vary at least within the limits which might naturally be expected between the no-load and full-load conditions of the generators. It is evident also that a variation of the frequency between these limits will result in throwing practically the whole load off or on the local generators. The only way that the local company can maintain a pre-determined load on the link which connects their system with the transmission system is to have the governors of all of their generators under control so that they can cause their system to follow immediately all of the continual slight changes in speed that are bound to occur in the transmission system. Such a scheme, while not impossible, would in most cases be impractical.

So far as experience and theory have thrown any light on the subject it may be stated in general that the unit which ties two synchronous systems together should have a capacity not less than one-half that of the smaller of the two systems so connected together. Even with a unit of this size any disturbance on either system may cause excessive loads to pass through the connecting link and in the case of a synchronous motor-generator set, will probably cause it to fall out of step. Also, there is no adequate method of adjusting the load on such a set during normal operation, a deficiency which practically debars such a unit from any extensive application.

There is a very good analogy for the connecting together of two alternating-current systems with a relatively small interconnecting unit, that shows at once the impossibility of successfully using a small unit for this purpose.

Imagine, if you will, a high speed, 500 ton passenger train run-

ning at a speed of sixty miles an hour—this corresponds to the transmission system. Imagine a parallel track immediately adjacent to the first track, on which runs a relatively light, self-propelled, 50 ton car, the desired speed of the train and car being the same—this car corresponds to the local plant. Imagine also that the grades on the two tracks do not necessarily come at the same places, that the first track may have an up grade while the second has a down grade, or vice versa. Now suppose that the car is so heavily loaded that it has not quite enough power to keep up the sixty mile speed that the train is making on the neighboring track. Suppose further that the train crew is willing to help the car to bring its speed up to that of the train. The question at once arises, what size of rope should be used to communicate the comparatively small amount of power that the car needs to take from the train. Using the same process of reasoning that seems so obvious in the case of the electric system, the result might be arrived at as follows:—The car requires a total tractive effort of about 20 lbs. per ton at sixty miles an hour on the level, or a total tractive effort of about 1 000 lbs. The addition of ten percent should enable the car to keep up to the required speed; consequently a rope that will transmit 100 pounds might be chosen. In order to have a factor of safety, a rope might be used that will not break until about 200 pounds is applied. With such a connection anyone can imagine what will happen at the first grade. Suppose that the train comes to a slight down grade at the same time that the car starts on an up grade. The speed of the train will tend to increase a little and that of the car to decrease. But the rope tying the two together compels them to maintain the same speed and the result is that for a short period a strain is thrown on the rope far in excess of the 100 pounds provided for and probably enough to break the rope. The only way the operator on the car can avoid having the rope strained or broken is to run his car with his eyes continually on the pull indicator (wattmeter) and his hand always on the throttle (governor), and even then it will be only with the greatest difficulty and with constant attention that the strain on the rope can be kept within the desired limits.

This analogy applies in still another particular. Suppose that while running at full speed with the tension on the rope adjusted to just the right value, the car encounters some obstruction and slows down suddenly. There will then be a sudden increase of rope strain to the breaking point. This is analogous to a short-circuit on the lines of the local plant when running in parallel with the transmission system.

A still further similarity may be mentioned. A train or car running at sixty miles an hour often has certain oscillations due to the irregular driving force of the locomotive. In other words, there are motions in trains and cars running at sixty miles per hour other than the steady straight-ahead movement. This corresponds in the electric system to a tendency to hunt. In the railway analogy these motions will throw a rapidly fluctuating strain on the connecting rope which may often be above the breaking point. In the electric systems the relatively small connecting link would be called upon to transmit momentarily an amount of power far in excess of its capacity.

In the railway analogy the remedy is to use a rope strong enough to stand any normal strain that might come upon it, that is, a rope that will pull the whole weight of the small car whether it is self-propelling or not. In the electric system the solution is similar; it is necessary to supply a connecting unit that will not break out of step, even when the whole power required by the local circuits must be taken through it from the transmission lines.

But this is an expensive method of accomplishing the desired result. If the local plant wanted to buy only 100 kw of energy from the transmission company, and for that purpose had to install a 1 000 kw transformer or motor-generator set, and, moreover, had to pay the transmission company on the basis of 1 000 kw of maximum demand, although only 100 kw were wanted, the proposition of buying power from the transmission company would not be an attractive one. If the cost of ropes were nearly as great as that of motor-cars, neither would the proposition of the 50-ton car borrowing 100 lbs. by means of a rope, capable of pulling the total of 1 000 lbs. needed for tractive effort from the 500 ton train, be attractive. The demand, therefore, is for a connecting unit that will transfer from the lines of the transmission company to those of the local company the 100 kw that the local company wants to buy to make out the 1 000 kw that constitute the total power requirements of the local company, just as the demand would be for a rope that will transmit from the 500 ton train to the 50 ton car the 100 lbs. pull, no more and no less, that the small car wishes to borrow from its larger neighbor. In the case of the rope an obvious answer will occur, namely, extensibility. Thus, if the connecting rope were made of rubber, it would simply be necessary to allow the small car to drop back far enough to acquire a predetermined elongation in the rope

and, therefore, the desired pull. By having on the car an adjustable winch with a sufficient supply of rope thereon, constant pull on the rope could be maintained in spite of conditions that would cause the car to drop a little further behind or forge a little further ahead of the position usually maintained with respect to the 500 ton train.

The stretch in the rope would be sufficient to take care of the end oscillations in the train or car and transmit practically the same pull in spite of it. If the car should suddenly slow down, due to its striking some obstruction which would cause an inflexible rope to break, it would simply mean increased momentary pull on the rope, which could be adjusted for by letting out rope from the winch. One other thing is apparent. The train can transmit a pull to the car only so long as the car lags somewhat behind. If the car is ahead of the train, or is just abreast, it is impossible for the train to exert any pull on the car.

For connecting together two electric systems there are devices analogous in a great many respects to both of the kinds of rope mentioned. The tying together of two alternating-current systems by transformers or by a synchronous motor-generator set is analogous to the use of a tow-rope. The use for this purpose of a motor-generator set, one or both of whose members is an induction motor (or generator) is analogous to the rubber rope. It is the substitution of the induction machine for the synchronous machine that introduces the element of flexibility.

In order to transfer power by the use of an induction motor-generator set it is absolutely necessary that the frequency of the generators of the local company be somewhat below that which would obtain if both units of the motor-generator set were synchronous machines and operated from the transmission company's lines. If both systems run at the same frequency no interchange of power will take place. If the local generators run at a higher frequency, power can be transmitted to the transmission system but cannot be received from it. In this regard the analogy of the train and car holds closely.

As to a quantitative statement of the necessary difference in frequency the following is approximate. The full-load slip of an induction motor varies from one to four percent or more, depending upon the design, size, etc. The difference in frequency between two alternating-current systems must be at least as great as the full-load slip of the induction motor used, if full-load of the set is to be transmitted from one system to the other. The other limit of the

frequency difference is a matter of economy. A slip regulator may be used in connection with the induction motor (or generator) by means of which any desired slip may be obtained. This is equivalent to the adjusting winch in the car and train analogy. However, in using the slip regulator it must be borne in mind that the percent of loss taking place in the motor-generator set is at least as large as the percentage of slip. For instance, if full-load of the motor-generator set can be transferred from one system to the other with a two percent slip, the use of ten percent slip will mean an additional eight percent loss that would not take place with the smaller slip.* It is necessary, therefore, that the slip of the smaller system with respect to the larger shall be at least two percent (or the full-load slip, whatever it may be), and it is desirable that the slip shall exceed two percent by as small an amount as possible.

In order to keep the amount of power taken by the local plant at a predetermined value the induction motor may be provided with an automatic slip regulator. In actual service this has been done and is the usual practice. It is equivalent in the train and car analogy to some device that would automatically adjust the winch so as to keep a constant strain on the rubber rope.

A word or two about the possible combination of poles in an interconnecting motor-generating set may not be amiss. Suppose the frequency of the transmission system is 25 cycles and that of the local plant 60 cycles. This is a typical case and the limitations outlined in the foregoing apply. If the two frequencies were exactly 25 and 60, the highest possible speed of the motor-generator set, synchronous on both ends, would be 300 revoluitions per minute, using 10 poles on the 25 cycle end and 24 on the 60 cycle end. If an induction machine is used, on either the 25 or 60 cycle end, a four pole motor and ten pole generator will work out well. Such a set will have a synchronous frequency of 62.5 cycles on the high frequency end if both machines are synchronous; i. e., its speed will be 4.17 percent fast. This excess above the true 60 cycle frequency is ample to allow for the induction motor slip necessary to transfer power from the 25 to the 60 cycle system and still allow the two systems to retain the exact frequencies for which they were laid out. In fact, when the load to be transferred is over 100 kw, the 4.17 percent slip allowed by the difference between 60 cycles and 62.5 is enough to transfer full-load when *both* machines are of the in-

*"The Induction Motor and its Characteristics," by A. M. Dudley, in the Journal for July, 1908, p. 376.

duction type, as the full-load slip of the wound-rotor motor of this capacity and over is usually not greater than two percent. Two such non-synchronous machines, one a motor and the other a generator, will therefore have a full-load slip not greater than four percent. However, it is desirable to have some leeway so as to allow for the transfer of more than full load when necessary. For this reason it is desirable to allow more than just sufficient slip.

If it is desired to change the direction of power transfer and have the 60 cycle system feed power to the 25 cycle system, the four and ten pole arrangement will probably no longer be satisfactory; for, supposing that the frequency of the 25 cycle system remains fixed, the 60 cycle system will have to rise to about 65 cycles before the condition of power transfer from the high frequency to the low frequency system will be as satisfactory as the former frequency ratio was for power transfer in the opposite direction.

To meet the condition of transfer of power from 60 to 25 cycles, a six pole motor and a 14 pole generator is about the proper ratio. Such a ratio of poles in a synchronous set if run from the high frequency end will give a frequency of 25.7 on the low end, or 2.8 percent high. This is margin enough under ordinary conditions to allow for the transfer of at least full-load through the set.

Economy in first cost demands high speeds in a motor-generator set. The normal speed of the four and ten pole set is 720 to 750 r.p.m. That of the six and 14 pole set is 500 to 514 r.p.m. Both of these speeds, therefore, tend to give fairly high economy so far as first cost is concerned.

Attention might be drawn to the fact that it makes no difference whether the motor or generator of such an interconnecting set is made the induction machine. If a four and ten pole combination is used with a four pole induction motor the speed of the set will be 720 r.p.m. and the four pole 25 cycle motor will have a slip of four percent below synchronism. If a ten pole induction generator be used the speed of the set will be 750 r.p.m., and the induction generator will have a slip of four percent above synchronism. If both machines be of the induction type the speed of the set will be about 735 r.p.m., the motor having a slip of about two percent below synchronism and the generator two percent above.

The determination of which machine should be of the induction type should depend upon which system is best able to furnish the exciting current demanded by the induction machine. The induction machine requires a certain amount of lagging current

from the system to which it is connected, no matter whether it is a motor or a generator and it should, consequently, be connected to the system that is best able to supply that lagging current.

Some of the possible pole combinations for a 25-60 cycle motor-generator set are given in Table I. All of the combinations for speeds of 250 r.p.m. and over are included. Consideration of first cost makes the ones given the only possible combinations of importance.

TABLE I.

25-Cycle Machine Poles.	60-Cycle Machine Poles.	Speed R.P.M.	Ratio of Poles. High Frequency. Low Frequency.	Ratio Needed. 60-Cycle. 25-Cycle.	Percentage of Slip
2	4	1500-1800	2.0	2.4	16.7 low(a)
2	6	1200-1500	3.0	2.4	25.0 high(a)
4	10	720-750	2.5	2.4	4.17 high(b)
6	14	500-514	2.33	2.4	2.78 low(c)
8	18	375-400	2.25	2.4	6.25 low
8	20	360-375	2.5	2.4	4.17 high
10	22	300-327	2.2	2.4	8.33 low
10	24	300	2.4	2.4	exact
10	26	277-300	2.6	2.4	8.33 high
12	28	250-257	2.33	2.4	2.78 low
12	30	240-250	2.5	2.4	4.17 high

(a)—The slip losses involved in using any possible combination with a two-pole machine (at least 16.7 percent with a two and four-pole combination and at least 25 percent with a two and six combination) removes at once the consideration of any two-pole machine as an interconnecting unit. There are other reasons leading to the same conclusions, but the above is controlling of itself.

(b)—As indicated in the foregoing discussion, this is a desirable pole combination to use when transmitting power from a 25-cycle to a 60-cycle system.

(c)—Desirable when transmitting power from 60 to 25 cycles.

SUMMARY

1—Two alternating-current systems should not be connected together by a transformer or synchronous motor-generator set of a capacity smaller than fifty percent of the smaller system.

2—If a transformer or synchronous motor-generator set be used between two alternating-current systems, the only method of regulating the amount of power taken through such a connecting link is to control the power output of the prime movers of one or both systems. With sudden fluctuations in load, accurate or rapid control of the power interchanged when using such a connecting link is practically impossible.

3—The proper method of exchanging power between two alternating-current systems is by the use of motor-generator sets, at least one of whose elements is an induction machine.

4—When using an induction motor as one of the links, the alternating-current system that receives power must operate normally at a frequency somewhat lower than the generator end of the connecting link would generate were the set synchronous on both ends.

5—The number of possible pole combinations that may be used in connecting a 60 and 25 cycle system is limited and the choice of combination should depend on the direction in which power is to be transferred.

The problem of furnishing a relatively small amount of power from one alternating-current system to another is, therefore, by no means as simple as might appear at first glance.

MAGNETIC LEAKAGE IN TRANSFORMERS

ITS EFFECT ON THEIR REGULATION UNDER NORMAL AND SPECIAL CONDITIONS

E. G. REED

IT IS generally known that the regulation of a transformer depends first, upon the voltage drop through the resistance of its windings, and second, upon a voltage drop resulting from what is commonly called magnetic leakage. The latter affects the regulation, particularly at loads of low power-factor.

While the subject of magnetic leakage has been analyzed mathematically with reference to transformers operating under normal conditions, some other very interesting phases of the subject are not so well known. For instance, certain special connections of individual transformers or of a group of transformers, often bring out the effect of this magnetic leakage on their operation in a striking manner. It is the purpose of this article to analyze some of these cases. In order to start with a clear physical conception as to the nature and effect of this leakage on the operation of a transformer under normal conditions, a brief outline of the usual method of treating this subject is given.

MAGNETIC LEAKAGE

A coil carrying an electric current establishes a magnetic field around it, as shown in Fig. 1. If this coil surrounds a magnetic circuit, as shown in Fig. 2, the greater part of the flux which before existed in the air now flows in the iron, magnetizing it at a given instant in the direction of the arrow. However, a small portion still flows around through the air as shown by the dotted lines in Fig. 2. If another coil be added to the magnetic circuit, as shown in Fig. 3, a transformer is formed. The first coil, taking current from the supply circuit, is called the primary winding and the second coil, delivering current to the load, is called the secondary winding. The load current in the secondary coil establishes a field around it in the air similar to that around the primary coil. According to the natural law of action and reaction the load current in the secondary coil tends to magnetize the magnetic circuit in a direction opposite to that of the primary; and the lines of force flowing in the air around the secondary coil are therefore in the opposite direction to those around the primary, as shown in Fig. 3. These lines of force which flow through the air are commonly called leakage lines.

The number of these leakage lines flowing in a given transformer is largely dependent upon the relative position of the primary and secondary windings. Assuming, for instance, a transformer whose primary and secondary windings are geometrically coincident, i. e., occupying the same space—an ideal condition which, of course, could not be realized in practice—the primary windings would tend to establish a leakage field around it in one direction and the secondary to establish a leakage field around it in the opposite direction, resulting in the non-existence of an actual leakage field. If, now, the primary and secondary coils be separated, the forces tending to establish fields around the coils, no longer being coincident and no longer annulling each other, set up leakage fields. Quantitatively this leakage will depend largely on the separation of the coils. Thus, if the coils are sufficiently separated, none of the lines of force from the primary coil will reach the secondary, in which case all the lines through the primary winding will be leakage lines. Since the leakage fluxes from the two coils join at the common point *A,* Fig. 3, it is evident that their effect is additive as far as the effect of magnetic leakage is concerned. Since the effect is additive, it is allowable, for the sake of simplicity, to think of all of the leakage lines as encircling the primary winding instead of being divided between the two windings as shown in Fig. 3. This equivalent leakage flux through the primary coil produces a counter-e.m.f. of self-induction which absorbs part of the impressed e.m.f. It is evident that this part of the impressed e.m.f. does not reach the secondary winding and, therefore, its magnitude is the measure of the magnetic separation of the windings. It will be interesting to note that the counter-e.m.f. due to the leakage flux is at right angles to the counter-e.m.f. due to the normal flux in the magnetic circuit at no-load. This, of course, assumes that the load current is in phase with the terminal voltage, i. e., that the transformer is delivering current to a non-inductive load. The phase relation of the counter-e.m.f. due to the leakage flux and the counter-e.m.f. due to the normal flux in the magnetic circuit at no load, becomes evident when it is considered that the leakage flux is in phase with the primary load current which in turn is displaced 90 degrees in phase from the normal flux in the magnetic circuit at no load.

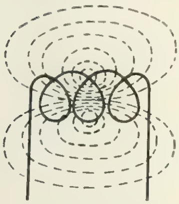


FIG. 1—MAGNETIC FLUX THROUGH A COIL IN THE AIR

It is possible to determine experimentally that part of the pri-

mary impressed voltage which does not reach the secondary and which is the measure of the magnetic separation of the windings. If the secondary of a transformer, the resistance of whose windings is negligible, be short-circuited, the voltage delivered to the load becomes zero, and the voltage impressed on its primary winding is only that required to balance the counter e.m.f. due to the leakage flux. This voltage, therefore, when normal full-load current flows through the short-circuited secondary becomes the measure of the magnetic separation of the windings. Of course a transformer winding possesses inherent resistance and in this test the impressed voltage is partly used in sending full-load current through this resistance. Considering the short-circuited transformer as an inductive coil, the impressed voltage required to drive full-load current through its windings is its impedance voltage. This impedance drop may be

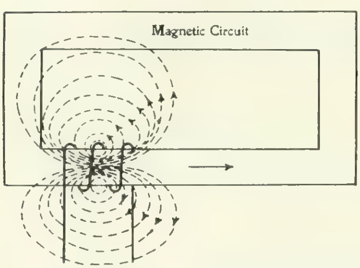


FIG. 2—A COIL ON A MAGNETIC CIRCUIT

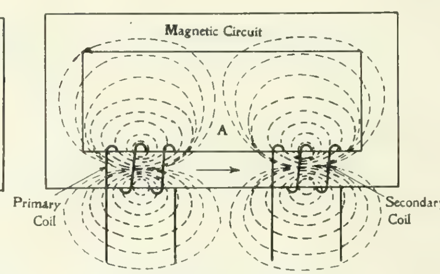


FIG. 3—MAGNETIC LEAKAGE LINES IN A LOADED TRANSFORMER

Showing leakage lines partly in air and partly in the iron.

resolved into two components at right angles to each other, the one in phase with the current being the resistance drop through the windings and the second being the reactive element which results from the magnetic leakage. It has already been shown why the component of the impedance due to the leakage flux is at right angles to the counter-e.m.f., due to the normal flux in the magnetic circuit.

The relations of these various factors and the effect of this magnetic leakage on the regulation of a transformer are shown by means of the well-known and very significant transformer diagram, Fig. 4. The impedance triangle may be drawn from tests on the transformer. These tests comprise measurements of the resistance of the windings and the impressed voltage necessary to circulate normal current through its windings with the terminals of the secondary coil short-circuited. In interpreting this diagram it will be

apparent that if the secondary terminal voltage remains constant, the length of the line representing the primary impressed voltage varies according to the position of the point E on the dotted arc of the

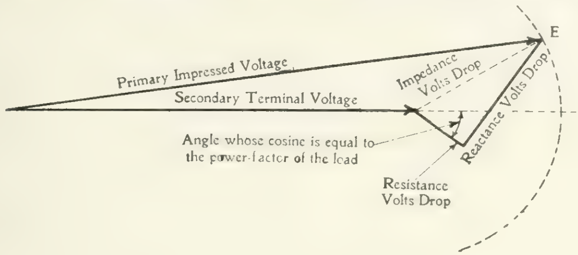


FIG. 4—TRANSFORMER DIAGRAM
Inductive load.

circle, the position of E changing according to the power-factor of the load to which the transformer is connected.

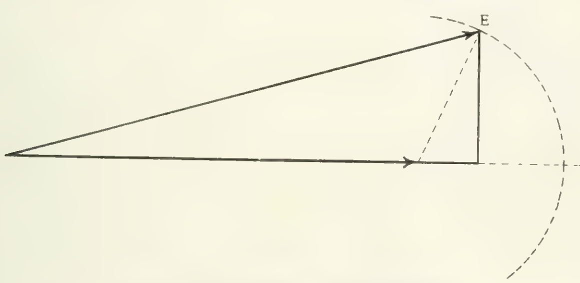


FIG. 5.—TRANSFORMER DIAGRAM
Non-inductive load.

Fig. 4 shows the condition of an inductive load, Fig. 5 of a non-inductive load and Fig. 6 of a capacity load. The difference be-

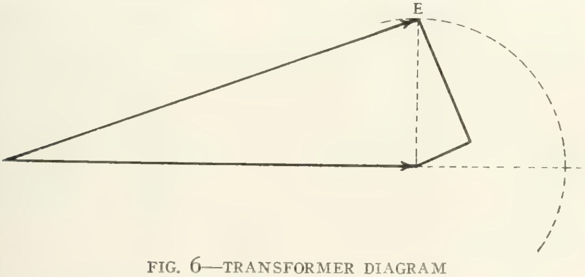


FIG. 6—TRANSFORMER DIAGRAM
Capacity load.

tween the impressed voltage and the secondary terminal voltage, expressed as a percentage of the secondary terminal voltage, is by definition the regulation of the transformer.

RELATIVE MAGNETIC LEAKAGE IN VARIOUS TYPES OF TRANSFORMERS

It has been shown that the reactive drop due to the leakage between coils is a measure of the magnetic separation of the various parts of a transformer winding. It will be interesting to show some approximate values of the magnetic leakage between the several parts of the winding of the three common types of distributing transformers shown in Figs. 7, 8 and 9. The core type transformer has two separate groups of the winding widely separated from each other, one being on each side of the core, as shown in Fig. 7. On the other hand, the windings of the shell type transformer with sandwiched coils is shown in Fig. 8. The windings of the shell type transformer with concentric coils somewhat similar to those on each side of the core type design are shown in Fig. 9.* An inspection of these figures will show the great difference in the relative magnetic separation of the various parts of the winding.

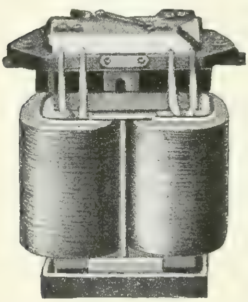


FIG. 7—CORE TYPE TRANSFORMER

In the light of the reactance figures given below the relative performance of the several types of transformers under various conditions of load may be predicted. These figures should not be taken as indicating directly the relative merits of the three types of construction, as they were obtained from different sizes of units and from different makes of transformers. The high magnetic leakages shown in Table I are not to be construed as indicating relatively poor regulation for this type of transformer, as they are due to the wide separation of the coils tested. When properly connected either for normal or special service, the regulation, as shown below, is quite good. The core type transformer shown in Fig. 7 with windings arranged as shown in Fig 10, has approximate reactances as shown in Table I.† Coils Nos. *1* and *2* comprise the low-tension winding and coils Nos. *3*, *4*, *5* and *6* comprise the high-tension winding. These reactance figures are determined as follows:—If coil No. 4, for example, be short-circuited, and voltage be impressed on coil

*For further information regarding this type of transformer see article by the author in the JOURNAL for July, 1909, Figs. 8 and 10, pp. 409 and 410.

†For the sake of simplicity the core type transformer, Fig. 10, has been represented with only one low-tension coil on each limb, i. e., coils *1* and *2*, whereas each winding is actually composed of two sections. This is warranted, however, by the fact that the leakage between these two sections on each limb is practically negligible.

No. *1*, the impedance voltage is, by definition, the voltage which will drive full load current through the two coils. Since the particular transformer under discussion is a 10 k.v.a. size, having voltages of 2 200 to 220 volts, the currents in the high and low-tension windings will be 4.55 and 45.5 amperes, respectively. The impressed voltage required on coil *1* to force these currents through the respective coils is 90 volts. Since the normal voltage of coil No. *1*, (being one-half the low-tension winding) is 110 volts, the percent impedance is $\frac{90}{110} = 82$ percent. The drop in voltage through the low-tension coil is $45.5 \times 0.01712 = 0.78$

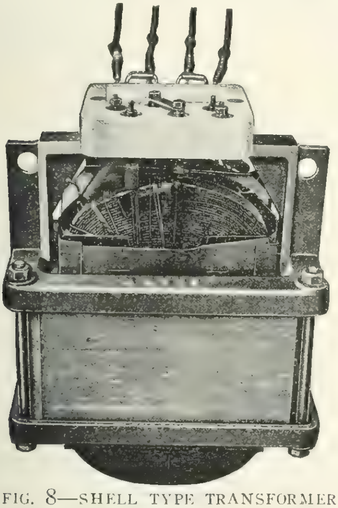


FIG. 8—SHELL TYPE TRANSFORMER
Sandwiched coils.

FIG. 9—SHELL TYPE TRANSFORMER
Concentric coils.

volts, which equals 0.71 percent of 110 volts, the resistance of one-half of the low-tension coil *1* being 0.01712. The resistance drop through the high-tension coil *3* is $4.55 \times 1.137 = 5.16$ volts, which is 0.94 percent of 550 volts. Therefore the total resistance drop is $0.71 + 0.94 = 1.65$ percent, the normal voltage of coil No. *1* being 110 volts and that of coil *4*, 550 volts.

Since the impedance drop is 82 percent and the resistance drop 1.65 percent, the reactance drop is $\sqrt{(82)^2 - (1.65)^2} = 82$ percent (practically). In this case the resistance drop is so small, as compared with the impedance drop, that it need not be taken into account. The other reactance values are determined in the same manner. The reactance value of this transformer connected up for normal operation is 3.42 percent.

The shell type transformer shown in Fig. 8, with the windings arranged as shown in Fig. 11, has approximate reactances as given in Table II, the determinations being made as explained in connection with Table I. The total reactance of this transformer connected for normal operation is 2.20 percent. Coils Nos. *1*, *3*, *4* and *6* comprise the low-tension winding and *2* and *5* comprise the high-tension.

TABLE I—APPROXIMATE LEAKAGE REACTANCES

BETWEEN VARIOUS PARTS OF THE HIGH AND LOW-TENSION WINDINGS OF A 10 K.V.A., 2 200/220 VOLT CORE TYPE TRANSFORMER, AS SHOWN IN FIG. 10

No. of Coil Upon Which Voltage is Impressed.	No. of Coil Short-circuited.	Percent Reactance.
1st	2nd	74
1st	3rd	14.5
1st	4th	82
3rd	4th	39.7
3rd	5th	22.4
3rd	6th	49.4

In the shell type transformer shown in Fig. 9, the high and low-tension windings are arranged in concentric coils as shown in Fig. 12, which represents a vertical section through the magnetic circuit and both sets of coils. Coils Nos. *1* and *2* comprise the

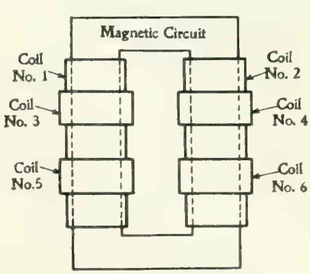


FIG. 10—ARRANGEMENT OF COILS—CORE TYPE TRANSFORMER

Coils Nos. 1 and 2, low-tension. Coils Nos. 3, 4, 5 and 6, high-tension.

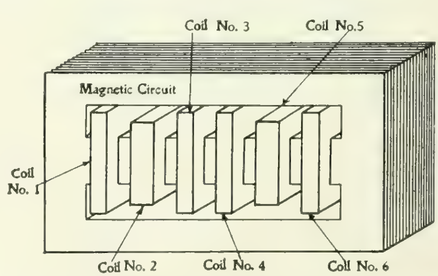


FIG. 11—ARRANGEMENT OF SANDWICHED COILS—SHELL TYPE TRANSFORMER

Coils Nos. 1, 3, 4 and 6, low-tension. Coils Nos. 2 and 5, high-tension.

low-tension winding and coils *3* and *4* comprise the high-tension winding. Approximate values of reactance of the various parts of the windings of a shell-type transformer with concentric coils are given in Table III. The reactance of this transformer connected for normal operation is 2.00 percent.

SOME EFFECTS OF MAGNETIC LEAKAGE ON THE OPERATION OF COMMERCIAL TRANSFORMERS

The service requirements of modern distributing transformers demand that they be wound for two voltages on the high-tension side, i. e., nominally 2 200 and 1 100 volts, and for three wire sec-

TABLE II—APPROXIMATE LEAKAGE REACTANCES

BETWEEN THE VARIOUS PARTS OF THE HIGH AND LOW-TENSION WINDINGS OF A 15 K.V.A., 2 200/220 VOLT SHELL TYPE TRANSFORMER WITH SANDWICHED COILS, AS SHOWN IN FIG. II

No. of Coil Upon Which Voltage is Impressed.	No. of Coil Short-circuited.	Percent Reactance.
1st	2nd	2.72
1st	3rd	5.33
1st	4th	6.50
1st	5th	8.12
1st	6th	10.65
2nd	3rd	4.68
2nd	5th	10.60
3rd	4th	2.34

ondary operation at nominally 220 volts across outside wires and 110 volts from each outside wire to neutral. This arrangement of winding is shown in Fig. 13. With one-half of normal load on one

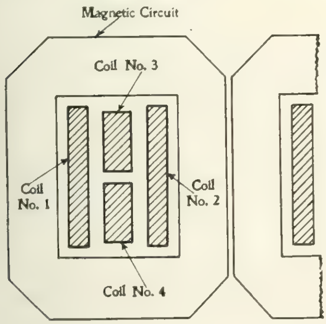


FIG. 12—ARRANGEMENT OF CONCENTRIC COILS—SHELL TYPE TRANSFORMER

Coils Nos. 1 and 2, low-tension. Nos. 3 and 4, high-tension.

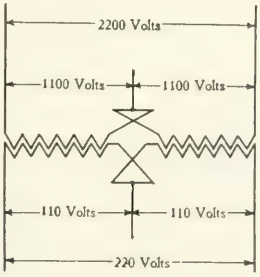


FIG. 13—TRANSFORMER CONNECTIONS

Two-voltage primary. Three-wire secondary.

side of the three-wire circuit, the voltages on the loaded and unloaded side should be practically equal.

Leakage in Core Type—Considering first the core type transformer shown in Fig. 7, if the windings are connected as in Fig.

14, with the primary coils in series, and the three-wire secondary is loaded on one side only, the voltage will be low on the loaded side and high on the unloaded side. This is due to the fact that coil No. *3* is not in close magnetic relation to coil *2* and there will be considerable leakage between them. Therefore coil *2* will act as if it had a higher impedance than coil *1*. Since coils *1* and *2* are in series and coil *2* has a higher effective impedance, the voltage across coil *2* will be greater than across coil *1*. Since the voltages induced in coils *3* and *4* are proportional to the voltages on coils *1* and *2*, (coils *1* and *3*, also *2* and *4*, being in close magnetic relation, with little leakage between them), the voltage on the loaded side will be much lower than normal and the voltage on the unloaded side much greater than normal. This condition will usually be exaggerated

TABLE III—APPROXIMATE LEAKAGE REACTANCES

BETWEEN THE VARIOUS PARTS OF THE HIGH AND LOW-TENSION WINDINGS OF A 7.5 K.V.A., 2 200/220 VOLT SHELL TYPE TRANSFORMER WITH CONCENTRIC COILS, AS SHOWN IN FIG. 12

No. of Coil Upon Which Voltage is Impressed.	No. of Coil Short-circuited.	Percent Reactance.
1st	2nd	7
1st	3rd	7.24
1st	4th	7.24
3rd	4th	15.9

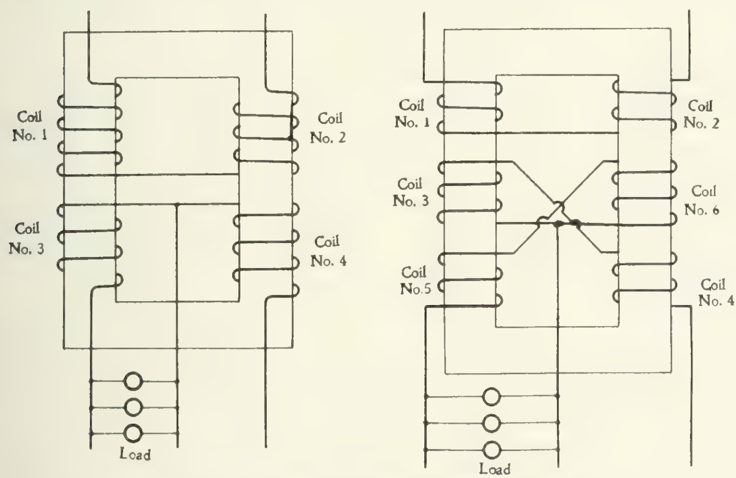
with the transformer in its case, due to the cast iron case assisting the flow of the leakage lines.

When coils *1* and *2* are in parallel instead of in series, the respective impressed voltages must remain constant and equal to each other; under these conditions the voltages delivered by coils *3* and *4* are practically equal under the various conditions of load. This, however, limits the primary voltage of the transformer to one value, and increases its cost, as each primary coil must be built for the full line voltage instead of for one-half its value.

In the early application of the core type transformer to commercial service, the arrangement shown in Fig. 15 was adopted, to overcome the objections outlined above. This connection is credited to Mr. W. H. Moody and is described in United States patent No. 595403, dated 1897. The reason for the successful operation of this arrangement is obvious from the figure. When one side of the three-wire system is loaded, both coil 5 and coil *6* receive the load

current, as they are in series. Coils 5 and 6 are in similar magnetic relations to coils *1* and *2*, so that the trouble experienced by the arrangement shown in Fig. 14 is avoided.

Leakage in Shell Type With Sandwiched Coils—The windings of the shell type transformer with sandwiched coils (See Figs. 8 and 11) may be connected as shown in Fig. 16, coil *1* being in series with coil *3* for one side of the three-wire circuit and coil *4* in series with coil *6* for the other side. In this case a condition exists somewhat similar to that resulting from the improper connection of the core type transformer, though in less degree. Coils *1* and *3* have a different magnetic relation to the high-tension coil *2* than they do to the high-tension coil 5. If, on the other hand, secondary coils *1* and *6*, *3*

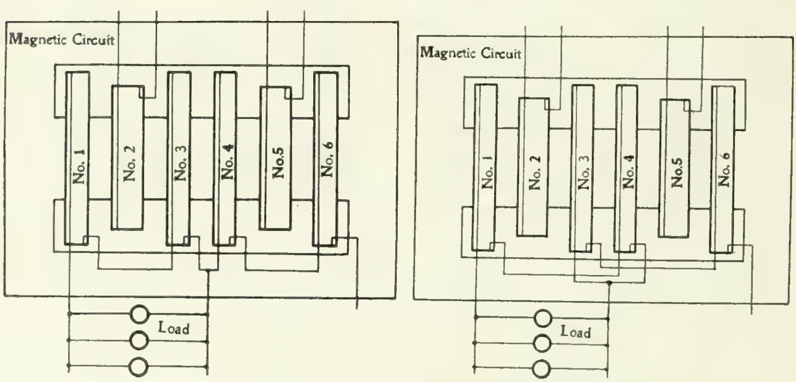


FIGS. 14 AND 15—CONNECTION OF COILS
Core Type Transformer.

and *4*, or *1* and *4*, *3* and *6* (as in Fig. 17) are connected in series for one side of the three-wire secondary circuit, balanced voltages in the two primary coils will be secured regardless of unequal secondary loading.

Leakage in Concentric Coil Shell Type—In the shell type transformer with concentric coils shown in Figs. *9* and *12* since the low-tension coils *1* and *2* are both in the same magnetic relation to the high-tension coils *3* and *4*, these two secondary coils may form the parts of the three-wire secondary system and will give balanced three-wire voltages, even with unbalanced secondary load. Since distributing transformers may be required, at times, to operate at half-voltage, or the two parts of the low tension winding may have to be

paralleled, the two parts must be made to have equal impedance. This necessitates that both coils *1* and *2* be wound in two parts and the resulting four parts be so connected as to make two circuits of approximately equal impedance. It is evident that the four parts of the low tension winding differ in both resistance and reactance. The inner part of coil No. *2* having the least resistance and the outer part of coil No. *1* the greatest. The parts of both coils Nos. *1* and *2* adjacent to the high-tension coils *3* and *4* have lower reactance than the parts farther away. If the resistance of the several parts of the low-tension coils is a predominating part of the impedance, the four parts must be connected to give equality of resistance. In this case the outer part of coil *1* must be connected in series with the inner part of coil *2*. In case the reactance is the predominating part of



FIGS. 16 AND 17—CONNECTIONS OF SANDWICHED COILS
Shell Type Transformer.

the impedance, the four parts must be connected to give equality of reactance. In this case the outer part of coil *1* must be connected in series with the outer part of coil *2*, and similarly with the inner parts of these two coils. In this way one coil in close magnetic relation to the primary coil is connected with another not so close in its magnetic relation. Similarly the two remaining coils are connected to give two circuits of approximately equal impedance.

EFFECTS OF MAGNETIC LEAKAGE ON THE OPERATION OF TRANSFORMERS UNDER SPECIAL CONDITIONS

Often with transformers operating under special conditions as, for instance, when employing the T-connection for two-phase—three-phase transformation, the conditions of load on some parts of the winding are abnormal. The relative operation of the various

types of distributing transformers under these special conditions of load is a matter of much interest. It is generally understood that the shell type of transformer with sandwiched coils, as shown in Fig. 8, lends itself particularly to this type of transformation, while on the other hand the impression has become prevalent that the ordinary form of core type of transformer, shown in Fig. 7 is not suitable for this transformation.

This, of course, is not true, as the successful operation of any type of transformer under these special conditions is merely a matter of the proper connection of the several parts of the primary and secondary windings for the individual case in hand. It is quite possible, of course, to connect the windings of the shell type transformer so that unsatisfactory results will be obtained. On the other hand it is possible to connect the windings of the core type transformer so that proper results will be obtained for this type. This aspect of the situation, though quite simple, is not generally understood. The several parts must be connected in a particular and definite way on account of the fact that the magnetic relations of the various parts of the windings are different.

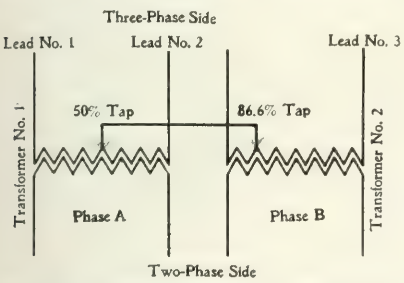


FIG. 18—CONNECTIONS FOR THREE-PHASE —TWO-PHASE TRANSFORMATION

Two-Phase — Three-Phase Transformation — An explanation of the T-connection for transforming from two-phase to three-phase or vice-versa has already appeared in the JOURNAL.* It will therefore suffice to state briefly that the transformation is accomplished by two single-phase transformers. On the three-phase side the middle point of the winding of one transformer is connected to one end of the other unit. The second transformer is wound for a voltage of 86.6 percent of that of the first, or an 86.6 percent tap is provided on a standard unit. The two leads of the first unit and the one lead of the second form the three-phase leads shown in Fig. 18. The two-phase circuits are indicated as phases A and B. If current be taken by phase A of the two-phase side, the current in the primary side must divide at the 50 percent tap as it flows out of transformer No. 2 and must pass through the winding of transformer No. 1 before it

*"Three-Phase—Two-Phase Transformation," by Edmund C. Stone, Vol. IV, p. 599, Oct. '07. See also descriptions of various modifications as referred to in Six-Year Topical Index of the JOURNAL, p. 16.

reaches the generator. In order that satisfactory results be obtained it is necessary that this current encounter no considerable impedance. It is usually stated that since the current circulates in one direction around the magnetic circuit on one side of the 50 percent tap and in the opposite direction around the core on the other side, they neutralize each other. It is evident from Fig. 18 that the currents on each side of this tap do actually flow in opposite directions around the magnetic circuit, since the winding from lead *1* to lead *2* is a continuous one. However, these two currents will not completely neutralize each other unless the parts of the winding on each side of this tap are so placed that they are in close magnetic relation, or in other words, so that the magnetic leakage between them is

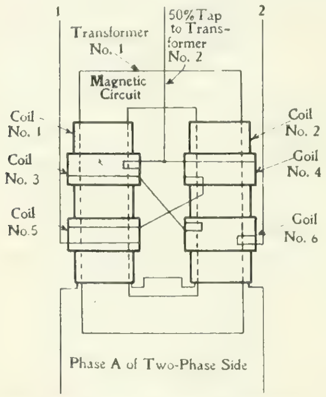


FIG. 19—CONNECTIONS BETWEEN COILS ON A CORE TYPE TRANSFORMER

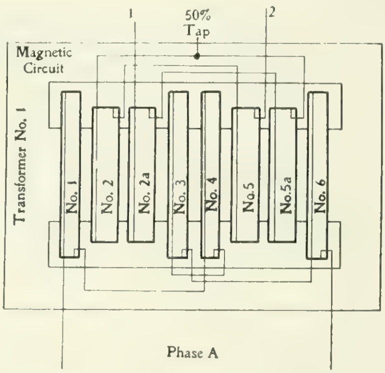


FIG. 20—CONNECTIONS BETWEEN COILS ON SHELL TYPE TRANSFORMER WITH SANDWICHED COILS

As arranged for three-phase—two-phase transformation.*

small. In case the current from transformer No. 2, in flowing through the primary of transformer No. 1 encounters considerable impedance due to magnetic leakage, an undue amount of the impressed voltage is absorbed in this impedance and consequently the secondary voltage of phase *B* is less than that of phase *A*.

The connections of a core type transformer corresponding to transformer No. *1* of the three-phase—two-phase set, Fig. 18, are shown in Fig. 19, connected on the high-tension side to minimize leakage between the two parts of the windings on either side of the 50 percent. tap, i. e., so that coils *3* and *5* and coils *4* and *6*, respec-

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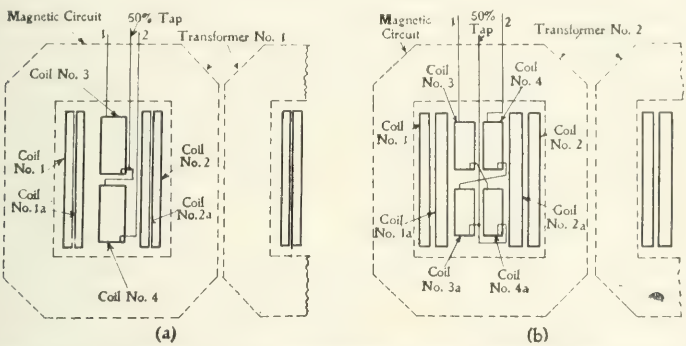
*On a standard distributing transformer coils *1* and *2*, the low-tension coils, ordinarily comprise two separate windings, these details being omitted here for purpose of simplicity.

tively, are closely related magnetically. The conditions are further improved if the two parts of the high-tension winding on each side are concentric and extend the whole length of each limb of the magnetic circuit. The corresponding connections for minimizing leakage on a shell type transformer with sandwiched coils are shown in Fig. 20, while those for the shell type transformer with concentric coils are shown in Figs. 21 (a) and (b). Because of the inherent design of the latter type of transformer the first of these connections gives sufficiently good results in the case of small transformers; but with the larger transformers of this type the high-tension coils, Nos. *3* and *4*, must be divided into two parts and interconnected as shown in Fig. 21 (b). It is obvious that, as in the case of the core type transformer referred to above, still better results will be accom-



FIGS. 21 (a) AND (b)—CONNECTIONS BETWEEN COILS ON SHELL TYPE TRANSFORMER WITH CONCENTRIC COILS

As arranged for three-phase—two-phase transformation.

plished if the four parts of the high-tension winding are made concentric and extend the whole length of the winding space. In the case of transformers of large capacities, the respective coils shown in these diagrams may comprise two or more separate windings, connected in multiple or series according to the various current and voltage requirements.

It is possible to compensate in another way for a large magnetic leakage between the parts of the windings on either side of the 50 percent tap. This is accomplished, however, at the expense of energy, which appears as copper loss; consequently it is not as desirable a method as that which accomplishes the same ultimate results by reducing the leakage to a small amount. This method is as follows:—Where the current divides in transformer No. 1 and flows either way, in case there is a large leakage and the current encounters considerable impedance, this impedance may be counteracted by

allowing a current to flow in the opposite direction around the magnetic circuit. This may be accomplished by providing parallel windings on the two-phase side of the transformer as shown in Fig. 22 These parallel windings provide a path for a local or circulating current which annuls the effect of the magnetic leakage. This will be apparent by reference to the directions of the arrows shown in Fig. 22. This circulating current obviously adds to the copper loss and is accordingly objectionable.

In order to determine definitely whether or not certain transformers will operate satisfactorily connected in T, it is necessary either to actually operate the transformers under load conditions or to get, by other means, a measure of the magnetic leakage between the two parts of the winding on either side of the 50 percent tap. A measure of this leakage, as indicated heretofore, can be obtained through measurement of the impedance by short-circuiting one side and impressing voltage on the other side, the impressed voltage being adjusted to give a value of current in the ammeter, connected as shown in Fig. 23, equal to that which enters through the 50 percent tap under normal conditions of operation. A large leakage, indicated in this test by a large impedance, will obviously result in unbalanced voltages on the secondary phases when the transformers are operated in T connection.

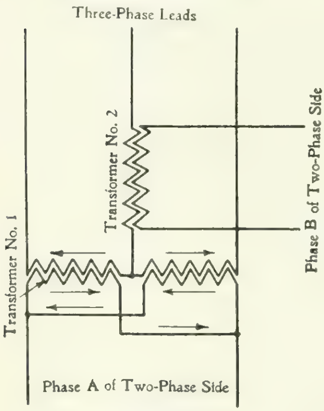


FIG. 22—INTER-CONNECTION OF SECONDARY COILS

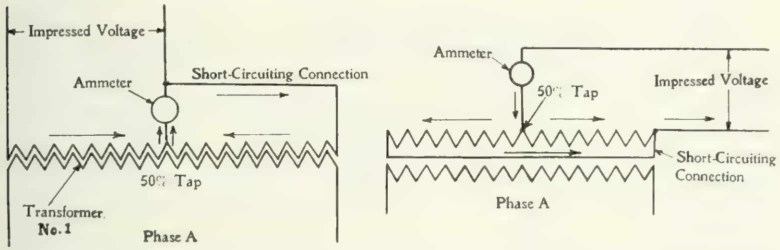
To avoid magnetic leakage in three-phase—two-phase transformation.

Another method may be employed to obtain data which may at once be used to give quantitative results as to the operation of transformers connected in this manner. If the terminals be short-circuited, as shown in Fig. 24, and voltage be applied as indicated, an impedance value is obtained, the reactive element of which is a measure of the leakage between these two parts of the winding. This impedance voltage is taken with a value of current flowing in at the 50 percent tap (as shown by the ammeter) equal to the normal current through the three-phase side of transformer No. 2. It should be noted that an impedance voltage taken as per Fig. 23 will have a value which is twice the value of a measurement taken as per Fig. 24. Both of these measurements, however, obviously indicate the

same amount of leakage. If, for instance, the value of this impedance as given by the method shown in Fig. 24 is five percent, the voltage of phase B will be decreased approximately five percent below that of phase A. In other words, the two-phase voltage will be unbalanced, phase *A* being approximately five percent larger than phase *B*. Accordingly, to show the same amount of leakage by the method of Fig. 23, the measured value of the impedance would be ten percent.

SUMMARY

The foregoing serves in general to show that the several types of transformers may, by a proper connection of the various parts of the windings, be made to operate substantially the same under



FIGS. 23 AND 24—MEASUREMENT OF IMPEDANCE IN T-CONNECTED TRANSFORMER

Means of determining amount of leakage between the two parts of transformer No. 1 of two-phase—three-phase set shown in Fig. 18.

normal and special conditions. The method of connection may be pre-determined by a study of the relative position of the various parts of the windings. By impedance and reactance measurements, data may be secured to pre-determine accurately the operation under any given conditions.

IMPROVEMENTS IN STREET LIGHTING UNITS

DUDLEY A. BOWEN

ONE of the most important factors in the improvement of street lighting during the past few years has been the development of flaming arc lamps. Of the two highly efficient illuminants of this type which have been developed, the carbon flaming arc lamp is deficient in both color and the distribution of its light. Where it is desired to illuminate a comparatively small area and the lamps can be hung rather high, and where the color of the light and the high maintenance cost are not objectionable, the carbon flaming arc may be satisfactory. But if it is desired to light large areas evenly with lamps giving a white light, spaced at some little distance apart, with low operating and maintenance costs, the

FIG. 1—PARK LIGHTED WITH SERIES DIRECT-CURRENT METALLIC FLAME ARC LAMPS

Illustrative of the results that may be obtained by this means as regards uniform exterior illumination.

carbon flaming arc is as unsuited as any of the earlier and less efficient arc lamps. These, however, are the conditions of ordinary street lighting, and it has been in meeting these conditions that the metallic flame arc lamp has been most successful. Its brilliant white light and high efficiency, and its characteristic light distribution are so peculiarly adapted to street and park lighting that it is rapidly superseding all other types of arc lamps.

The metallic flame arc lamp has been on the market for several years, and has operated with marked success. An example of its application to park lighting showing the uniform illumination secured over the entire illuminated area, is given in Fig. 1, which shows

a section of North Side Park, Pittsburg, lighted with four ampere, series metallic flame arc lamps. This photograph was taken about 9 P.M., the slight brightness of the sky being caused by the reflection from the city lighting system. The high candle-power of this type of lamp at slight angles from the horizontal results in nearly as much light between the lamps as in their immediate proximity, producing the exceptionally uniform illumination shown in the photograph. It is interesting to note that these lamps replaced enclosed direct-current series arc lamps, and give much better illumination, with a very material reduction in current consumption. The number of lamps fed from an already overloaded power station was thus considerably increased without making it necessary to increase the generating capacity.

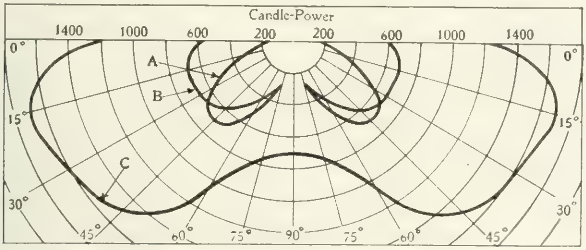


FIG. 2—LIGHT DISTRIBUTION AND CANDLE-POWER CURVES OF ARC LAMPS

A—Series direct-current enclosed arc lamp, 6.6 amperes, 500 watts.

B—Series direct-current metallic flame arc lamp. 4 amperes, 272 watts.

C—Series direct-current metallic flame arc lamp. 6.6 amperes, 450 watts.

The light from the metallic arc lamp is of a pure white character and very brilliant. A comparison of the relative candle-power and light distribution of an ordinary series arc lamp and metallic flame arcs burning at four and at 6.6 amperes is given in Fig. 2. From these curves it may be seen that a four ampere metallic flame arc lamp with a power consumption of only 272 watts, gives greatly increased light values at the useful angles as compared to a 6.6 ampere direct-current enclosed arc consuming 500 watts. The values of the metallic flame arc lamp at angles from zero to 45 degrees below the horizontal are all above 600 candle-power and at angles from zero to 20 degrees below the horizontal, the angles at which the light is most useful for street lighting, they are approximately double those from the enclosed arc

lamp. The 6.6 ampere metallic arc lamp gives approximately the same light distribution as the four ampere lamp with greatly increased efficiency and is available where increased illumination is desired with the same light distribution and excellent operating characteristics of the smaller lamp.

The distribution curve of the metallic flame arc lamp has been found to be very nearly ideal for the usual spacings of street lamps. There is sufficient light underneath the lamp, and with the maximum candle-power directed at an angle of 15 degrees the illumination becomes quite uniform between lamps. With a series circuit operated from an alternating-current generator and a mercury rectifier it is possible to operate these lamps from either a 60 cycle or 25 cycle alternating-current system. As other types of arc lamps cannot be operated at 25 cycles, this feature is of much value for companies using the lower frequency.

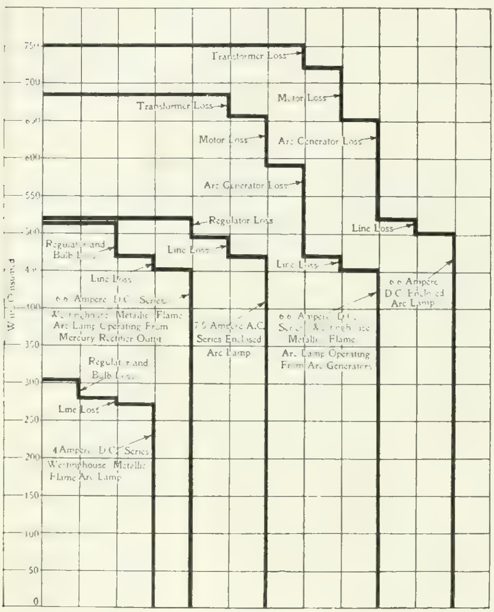


FIG. 3—ANALYSIS OF LOSSES IN DISTRIBUTION, FOR TYPICAL INSTALLATIONS EMPLOYING VARIOUS TYPES OF LAMPS

The distribution losses for typical installations of the various types of lamps and systems are shown graphically in Fig. 3. In this diagram the number of lamps, size of wire and length of circuit is assumed the same in each case and the watts consumed in each part of the circuit are represented to scale. The efficiencies of the three different types of circuits given are as follows:—

Series direct-current, with motor driven arc machines . . . . 66 percent
Series alternating-current, with constant current transformers 90 percent
Series direct-current, with mercury vapor rectifiers and regulating transformers operating from alternating-current supply . . . . 88 percent

In considering the efficiencies, the great reduction in total wattage of the circuit which can be made by the use of metallic flame arc

lamps without any decrease in illumination must not be overlooked, as this determines the total efficiency of the system.

In the metallic flame lamp the arc is struck between a metallic negative electrode, whose constitutents are carefully selected to give the desired volume of vapor and color of flame, and a positive button of copper alloy which is of ample size to radiate the heat and whose oxides, when fused into a slag, will form a good conductor when cold. The arc has a non-luminous zone near the positive electrode and an intensely bright luminous zone, composed of volatilized oxides near the negative electrode and closely resembling in shape an ordinary candle flame. In order to secure the most desirable light distribution, as well as to secure simplicity of operating mechanism, the negative electrode is preferably fed from the top. The life of the negative electrodes per trim is, for the four ampere lamps, about 200 hours, and 90 to 100 hours for the 6.6 ampere lamps.

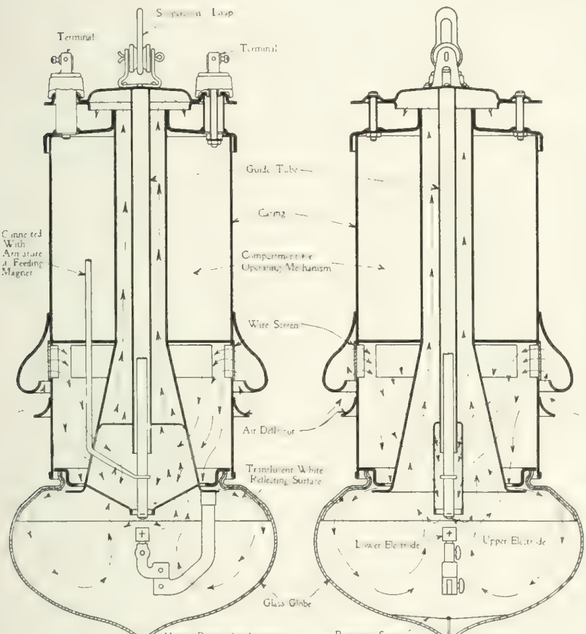
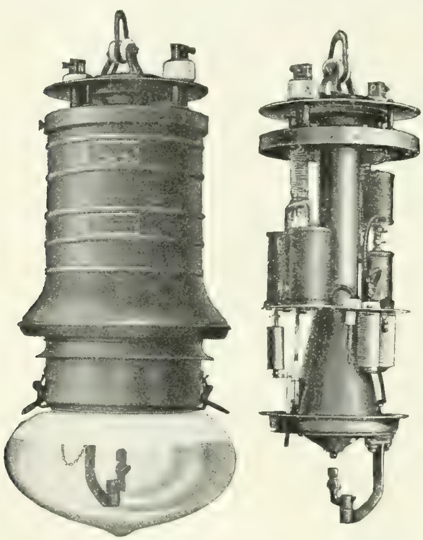


FIG. 4—TWO DIAGRAMMATIC CROSS-SECTIONS OF SERIES DIRECT-CURRENT METALLIC FLAME ARC LAMP, SHOWING IMPROVED METHOD OF VENTILATION

In the latest improved type of Westinghouse metallic arc lamp, the arc has been lowered in the arc chamber so that the light distribution is slightly better than in the older form. The electrode, as it is consumed, is fed by the lamp mechanism, so as to maintain the proper position with reference to the metal button. The products of combustion from the arc, if allowed to come in contact with the cold surfaces of the globe, will be deposited and obstruct the light. It is therefore necessary to provide some means of convey-

ing the products of combustion from the arc chamber. This is accomplished by means of an air draught which circulates inside the globe around the electrodes and thence up a central chimney. In the most recent type of lamp the ventilating ducts have been increased in size so that the natural draught is practically doubled. The draught also helps to center the arc and holds it remarkably steady. The improved draught scheme is shown clearly in Fig. 4. This scheme has proven very satisfactory and has practically done away with any trouble due to dirty glassware. A light metal screen is placed in the bottom of the globe to protect the glass from any particles of hot slag that may fall from the arc.



FIGS. 5 AND 6—EXTERIOR AND INTERIOR VIEW OF LATEST TYPES OF SERIES DIRECT-CURRENT METALLIC FLAME ARC LAMP.

The general appearance of the lamp has been modified, the size and weight both having been reduced. Figs. 5 and 6 show the new lamp complete and with the case removed. The over-all length is 30 inches and the weight complete 35 lbs. The case is made of solid copper with black weatherproof finish. By loosening a thumb-screw at the top and turning the case slightly, it can be entirely removed, thus exposing the entire mechanism for inspection. The glass globe is supported by cam latches at opposite sides, and is entirely removed when the lamp is trimmed. There is only a small number of parts in the lamp mechanism and these are easily accessible. Solid mica and porcelain insulation is used throughout, so that insulation troubles have been reduced to a minimum.

From a commercial standpoint, the metallic flame arc lamp is of great interest both to the central station and general public. By the use of this type of lamp with its decreased current consumption and increased life per trim, nearly twice as much light with greatly superior light distribution can be furnished a given area for the same maintenance and operating costs as with the older arc lamp systems, or an equivalent lighting service can be furnished with only one-half the former energy consumption.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

426 — Power-Factor Correction — Our system is three-phase, 34 500 volt, 60-cycles; average load about 1 200 kw; power-factor, 80 percent. The line consists of 15 miles of No. 4 copper wire on four ft. triangle. I have calculated that a 200 kw condenser will raise the power-factor to 87 percent and thought to effect a saving of one kw. However, unless my method is quite wrong, there will be some loss, this amount being where I want assistance. Following the method of calculation in a recent article in one of the technical periodicals: "Power Loss = Resistance volts per ampere per mile × miles × amperes × line volts. Resistance per ampere per mile=2.6. Length of line, 15 miles. Current per line with power-factor of 80%= 21.74 amperes (1.55 percent loss). Current per line with power-factor of 87%= 20 amperes (1.32 percent loss). Loss with power-factor of 87%=2.26; improvement=0.2 percent. According to another article, giving a method of determining the magnitude of the line loss in a transmission line, I find the line loss at 80 percent power-factor to be 3.71 percent and at 87 percent power-factor to be 3.07 percent. Difference due to change in power-factor=0.64 percent. As it takes 16 kw to drive the machine and 4.8 kw for field excitation, the input =20.8 kw and the saving in line loss by the first method=2.4 kw. The loss is 18.4 kw with condenser. By the second method the loss would be 20.8—8.14= 12.66 kw. Please explain wherein my difficulty lies. V. J. C.

For method of figuring line loss see article on "Drop in High Tension Transmission Lines," by Mr. R. D. Mershon, in the JOURNAL for March, 1907, p. 137. With line constants as given above, the losses at 80 percent and 87 percent power-factors as obtained by the application of this method are found to be as follows:—

At 80% P-F = $15 \times 2.63 \times (21.74)^2 =$ 18.65 kw loss.

At 87% P-F = $15 \times 2.63 \times 20^2 = 15.78$ kw loss.

In this particular case it would be advisable to install a synchronous condenser only in case it is desired to relieve overloaded generators or to take more power from them. The line loss is too small to be considered of itself. A condenser should be as close to the low power-factor load as practicable. If located in the power house only the generators receive the benefit; the transformers and transmission line are then carrying the same wattless current as before. The field current of alternating-current machines increases rapidly as the power-factor falls below unity; therefore the output at low power-factor operation is limited by either the field I R drop or the field temperature. Therefore, when considering the use, as synchronous condensers, of machines not especially designed for such purpose, it must first be determined as to whether they will be capable of delivering their rated k. v. a. output at zero power-factor. S. N. C.

427—Effect of Method of Connection on Capacity of Three-Phase Rheostat—We are using a water cooled rheostat consisting of iron wire coils connected in delta as an artificial load on a 2 300 volt, three-phase circuit. When so connected the rheostat takes a load of 2 500 kw. With the three sections connected in star, would the load be 2 500 ÷ $\sqrt{3}$ or

would it be 2 500÷3, the bus-bar voltage remaining constant?

E. C. R.

Power in each section of a resistance varies as the square of the voltage across it. This follows from Ohm's Law ($I=E/R$), since

$$W = EI = E \times \frac{E}{R} = \frac{E^2}{R}$$

The star voltage = delta volts ÷ $\sqrt{3}$; therefore *star* power = *delta* power÷3. This applies to each of the three equal sections of resistance; hence the total load taken by using a star connection will be one-third that by the delta connection.

H. M. S.

428—Induction Motor Operated Above Synchronous Speed—If an induction motor is operated above synchronism as a generator, the direction of rotation being the same as its direction if operated as a motor, will its voltage be added to or subtracted from that of the line? If the motor were operated in the opposite direction of rotation or the connections reversed so as to change the phase relations, what would be the result? B. L.

The effect of increase of speed above synchronism is to cause a leading power-factor, i. e., the current is caused to lead the voltage. The primary voltage is not affected. Under these conditions the motor has the same characteristics above synchronism as below. Thus the magnitude of the leading current is proportional to the excess of speed above synchronous speed (corresponding to the slip). An induction motor operating in this way is commonly known as an induction generator and is effective in correcting (raising) the power-factor of a circuit carrying inductive load, as its leading current tends to neutralize the lagging current of the inductive load. In contrast with a synchronous motor over-excited to give leading current, it cannot carry mechanical load because of the fact that it can receive its excitation only through the primary circuit and is thus strictly an integral part of the system on which it is operating; hence, strictly speaking, it is not a generator. For further data note article by Mr. H. C. Specht, on "Induction Motors for Multi-Speed Service, with Particular Reference to Cascade Operation," Proc. A. I. E. E., June, '08, p. 791, in which are given characteristic induction motor curves, showing the effect on secondary frequency, speed, voltage, etc., of operation both above and below synchronous speed. The effect of reversing the primary connections of the motor or of operating it in a direction opposite to that in which it would operate as an ordinary motor, is to approximately double the secondary frequency and to excessively increase the primary current.

H. C. S.

429—Division of Load and Excitation of Alternators Operating in Parallel—Why is the load of two or more alternators operating in parallel said to be independent of the field excitation? Does the machine with the weaker field run as a motor with a negative load? B. L.

You doubtless have in mind the following conditions: Assuming two alternators operating in parallel, the one having a more liberal field margin than the other; when operating under load and proper field adjustment has been made, there is a tendency for the former to supply a leading current to the machine having the weaker excitation, which serves to excite the latter machine sufficiently to cause it to take approximately its share of the load. J. B. W.

430—Books on Uses of Oils—Do you know of any good books on uses of oils, such as for insulation, lubrication, etc.?

The following may be of assistance: "Friction and Lubrication," by Wm. M. Davis, 325 pp., \$2.00; "Lubrication and Lubricants," by Leonard Archbutt and R. Mountford Deeley, 528 pp., \$6.00, especially adapted to the subject of lubrication, its history, etc.; "Oils, Fats and Waxes," Dr. J. Lewkowitsch; Chemical technology and analysis, dealing more especially with vegetable oils; three volumes, \$15.00; "Lubricating Oils,

Fats and Greases," G. F. Hurst, (1902) 313 pp., \$3.00; "Practical Treatise on Friction, Lubrication, Fats and Oils," E. F. Dietrichs; (1906), 132 pp., \$1.25; Stillman's "Engineering Chemistry," (1905), 579 pp., \$4.50, containing a few chapters on oil and lubrication. Much valuable information regarding the use and treatment of oil used for insulation purposes is to be found in the various references given in the Six-Year Topical Index of the JOURNAL. T. D. L. & L. F. V.

431—Starting Inductor Alternator. —Can a 300 kw 2 300 volt, 60-cycle, two-phase, Stanley inductor alternator be operated as a sychronous motor on a 2 400 volt, three-phase circuit through three-phase — two-prase, 500 kw transformers? Can it be started and brought into synchronism with the power circuit by connecting it to the circuit through suitable control apparatus, depending on its starting as a synchronous motor, without the application of external power? It is desired to supply power to a counter-shaft from which several Brush arc machines are driven Would rheostatic or auto-transformer control be best for starting, or is it allowable to impress full line voltage directly on the motor circuit? A 500 volt, direct-current circuit is available in case a separate starting motor would be preferable. M. H. L.

This inductor alternator can doubtless be operated as a synchronous motor from a three-phase, 2 400 volt circuit through transformers giving two-phase, 2 300 or 2 400 volts. Transformer connections of course would be made through two single-phase transformers connected for three-phase—two-phase transformation. Some inductor alternators are not self-starting when run as synchronous motors. It may, therefore, be necessary to bring the motor up to synchronous speed by the use of a starting motor. Any alternating-current generator may be operated as a synchronous motor when properly connected to the source of power. Whether or not it will be self-starting depends upon the construction of the machine. The starting torque of the induction motor is due to induced reactive currents in the rotor winding and the synchronous self-starting motor obtains its starting torque in the same manner, since it is provided with proper sized rotor-bars or conducting grids in the pole pieces, through which currents may circulate. See article on "Self-Starting Synchronous Motors," by Mr. Jens Bache-Wiig, in the JOURNAL for June, 1909, p. 347. J. E. C. & L. W.

432—Speed of Wattmeters and Shunt Motors—Why does an integrating commutator wattmeter run faster on increase of load, i. e., field strength, whereas a shunt motor decreases its speed when the field current is increased? This is the way I look at it:—Assume a constant line voltage across both meter and motor. In a shunt motor, running without load, the current in the armature depends on the counter-e. m. f. On increasing the field strength the armature rotates slower in order to cut the lines of force at the same rate and hence maintain a constant counter-e. m. f. In the case of the meter the armature has no iron, hence there is no counter-e. m. f., but there is the ohmic resistance which holds the current constant. Now, with a fixed current in the motor and meter armatures, why should not both act the same on increase of field strength? Wherein lies the flaw in this reasoning? R. A. P.

In the first place, the statement is misleading, that in a shunt motor "the current in the armature depends on the counter-e. m. f." It should, of course, be understood that the stationary coils of the meter which produce the field carry the line current while the armature circuit of the meter is connected across the line. It is true that an integrating commutator motor is in some respects similar in principle to a shunt motor, but it differs in that there is a high resistance in series with the armature of the motor so that practically all the e. m. f. applied

at the terminals is used in overcoming resistance and practically none in overcoming counter-e. m. f. The armature current in the meter is practically the same at any speed and is proportional to the voltage. The torque on the armature, being proportional to the armature current, is proportional to the e. m. f. and, being proportional to field strength, it is proportional to field current, i. e., the line current. Thus the torque is proportional to e. m. f. and current, and the speed which is controlled by the damping due to a permanent magnet, is proportional to the torque. Thus it is evident that the speed is proportional to the watts. H. W. B.

433—Allowable Drop, Arrangement of Circuits and Calculations of Drop in Distribution System—(a) What may be considered as a maximum allowable line drop for secondary distribution circuits of 115 or 230 volts? (b) In laying out the secondary lines of a lighting system, i. e., the primary distribution circuits, is it advisable, when considerable territory is involved, to use circuits of some length and sufficient carrying capacity to supply the secondary distribution, or is it advisable to use shorter lines of lighter wire and more transformers? (c) What may be considered as an allowable drop in two miles of 2 300 volt, three-phase, 60-cycle, primary distribution lines? (d) Is it necessary to know the resistance and reactance drop of the transformers of a transmission circuit in order to figure correctly the power, line loss, etc? H. W. R.

(a) Good lighting service demands that the variation in voltage at the terminals of the lamps shall not exceed two percent of the applied voltage. Any system of distribution and operation which keeps the voltages upon the lamps within this limit would be considered satisfactory. The maximum allowable drop will depend upon two things; first, the extent to which line drop can be successfully compensated for by feeder regulators, etc., at the central station; and second, the extent to which undesirable conditions as to voltage regulation at lamps can be endured. (b) The modern tendency is to use secondary circuits feeding a number of customers where the district fed is a congested one. This secondary circuit may be fed from one or more points. For instance, if a block of residence lighting is to be taken care of, it is considered good practice to run a low voltage circuit completely around the block and tap the individual residences on to this low voltage circuit. The low voltage circuit can in turn be fed from transformers located at, say, two points, which would be preferably on opposite sides of the block. Where the load is isolated and the individual users are separated by comparatively large distances, individual transformers are practically a necessity. For conditions intermediate between these, a scheme which would be a compromise between the two would have to be used, depending entirely upon the local conditions to be met. (c) The maximum drop which would be allowed in a circuit as above described would depend entirely upon the nature of the load being supplied. If the load consists of lighting the drop should be kept within such limits as will satisfy the conditions named in the answer to (a). If the load consists entirely of motors, much larger drop may be allowed; ten percent being not excessive for such conditions. Further, if the drop in the high-tension transmission line can be compensated for at the power house, then a considerably larger drop is allowable than is otherwise the case. Such compensation at the power plant might further depend upon whether there is a single circuit or a multiplicity of circuits to be taken care of. In short, the question demands more data before it can be answered explicitly. (d) It is necessary to know both the reactance and the resistance drop in a transformer in order to figure the total drop that will occur in any circuit fed from that transformer. Moreover, the total drop depends largely upon the

power-factor of the load supplied. If the load supplied consists entirely of lights or is known to have a power-factor of 100 percent, the only drops, either transformer or line, that need be taken into consideration are those due to resistance. If, however, the power-factor is lower than 100 percent, then both the reactance and resistance drops of the transformers must be taken into account in order to obtain the total drop. The space here is too limited to indicate the methods of calculating drop with various power-factors. No. 206, Feb., 1909, may be of assistance in this connection. For further references, see pp. 17-18 of the Six-Year Topical Index of the JOURNAL.

P. M. L.

434—Use of Condenser in Telephone Circuits—Please give details regarding the use of condensers in telephone circuits. I understand that they are used selectively, allowing passage of alternating current, at the same time giving the effect of an open circuit so far as direct current is concerned. I especially want to know what effect the capacity of the condenser has on the circuit. Is the resistance factor involved at any time? Why is a two-microfarad condenser so frequently used? F. H. W.

The use of the condenser is, as suggested by the writer, for the purpose of preventing the flow of direct current while permitting the flow of alternating current. The condenser is very largely used in the circuit of the telephone bell to prevent the leakage of battery current from the central battery offices to ground through the ringer circuits. The two-microfarad condenser is used because it has the necessary conductance to allow the passage of the ringing current, while a smaller condenser does not prove satisfactory in that connection. When placed in talking circuits, the condenser is usually multipled with one or more similar two-microfarad condensers. The two-microfarad size being a convenient unit, it is customary to place two or three two-microfarad condensers in parallel rather than use a single four or six-microfarad condenser. When placed directly in a talking circuit the condenser, of course, introduces a certain amount of impedance; however, as the talking frequencies are high, the impedance is very low. E. B. T.

435—Adjustment of Load Between Paralleled Rotary Converters—Two similar rotary converters are operating in parallel on a fluctuating load. Proper division of load is not obtained. The brushes are set at the same commutating points on both machines. Can the difficulty be overcome by adjusting the series field shunts? E. U. R.

If there are two or more rotaries operating from one bank of transformers, so that they are in parallel on both the alternating-current and direct-current sides, proper division of load requires equal resistance drops in the leads, brushes and armatures of the respective machines, and proper adjustment is practically impossible. If there is a separate transformer bank for each rotary there should be no difficulty in obtaining the proper division of load by adjustment of the resistance of the series field or of the equalizer circuit. F. D. N.

436—Parallel Operation of Rotary Converters—Two compound wound rotary converters placed in sub-stations five or six miles apart operate successfully in parallel, feeding into a common direct-current railway circuit. What are the factors which serve to cause satisfactory parallel operation under these conditions? Why does not one machine tend to take all the load?

G. T. S.

When the machines are separated by some distance, as in the present case, that machine nearest the load will tend to take the greater portion of the load, the unequal loading being caused by the unequal resistance in the two parts of the direct-current line circuit (on either side of the load) as the cars approach nearer to the

one sub-station than to the other, i. e., the line circuit could be considered as a part of the leads from the machine to the point of paralleling. This difficulty can be overcome by giving the rotary converters a slightly drooping characteristic. Line drop is then compensated for by increase in voltage on the machines farthest from the load. This latter method is practiced on one of the large systems in New York City. For further information on operation of rotaries in parallel see article on "The Voltage Regulation of Rotary Converters," by Mr. P. M. Lincoln, in the March, 1904, issue of the JOURNAL, p. 55; also "Hunting of Rotary Converters," by Mr. F. D. Newbury, June, 1904, p. 275.

H. M. S.

437—Testing Dielectric Strength of Transformer Oil—The following apparatus was employed for testing transformer oil used in connection with apparatus for voltages from 2 000 to 17 000 volts, Three 2 kw transformers, 100 volts secondary, 15 000 volts primary, were connected in series to the primary side to give a maximum testing voltage of 45 000 volts. Voltage control was obtained by means of a water rheostat connected to the 100 volt side. The oil testing outfit consisted of a glass jar five inches wide by 3.5 inches deep, the oil being three inches deep. The primary leads were carried into the jar, four inches apart, through vacuum glass tubes of one inch diameter. Terminals of flat surface 0.375 inches wide were used, set to give a 0.2 inch gap. These were immersed midway in the oil in a horizontal position. Are these relations correct? L. J. T.

Details regarding standard apparatus and methods for testing of oil, and results to be anticipated are covered in various articles and questions appearing in the JOURNAL as referred to on page 17 of the Six-Year Topical Index. See, also, No. 372, Jan., 1910. In order to obtain absolute results, standard apparatus must be employed for testing the dielectric strength of oil. The use of polished rounded terminals of a fixed size for the gap is necessary, as the presence of sharp edges results in concentration of voltage stress at these points and, consequently, giving a lower breakdown value than would be obtained with standard rounded terminals. It is also necessary that the gap should be at a certain fixed depth in the oil. The terminals must also be out of contact with the walls of the retaining vessel with ample clearance distance. A water rheostat employed as suggested has the effect of distorting the e. m. f. wave form in the testing circuit from a sine wave form, the result being a deviation from true results proportional to the amount of distortion. The importance of pursuing some acknowledged standard method of testing is thus quite obvious, as is also the explanation of the apparently low results obtained. C. E. S.

438—Method of Re-magnetizing Permanent Magnets—Please give information as to the method of re-magnetizing permanent magnets of a magneto used for ignition purposes on an automobile. H. P. F. D.

These permanent magnets can easily be re-magnetized, without dismantling the magneto, by winding a temporary coil of say twenty to forty turns of No. 14 flexible cord or cable around the assembled magnets, and switching this coil directly upon a 110 volt direct-current circuit having considerable ampere capacity, a five or ten ampere fuse being first connected in series with the coil. This fuse will be blown with considerable violence, after which the temporary coil is to be unwound. The magneto armature should never be withdrawn from its normal location between the poles of the magnet, but should be blocked during the magnetizing process, in such a position that the iron shoes of the H armature will lie in the neutral or "half way" position between the poles of the magnet, so that no material magnetic flux will pass through the armature winding.

J. L. A.

THE

ELECTRIC JOURNAL

Vol. VII JUNE, 1910 No. 6

Systems of Railway Electrification

It is little to be wondered at that there is a confusion of ideas regarding the various systems in use for electric traction, when one considers them in all their details. A careful examination of three-phase, single-phase and direct-current installations in this country and in Europe has convinced the writer of the utter futility of comparing the systems on the basis of present installations. In every case the installation has some peculiar condition to meet which renders it unfit for comparison as to system, even in the most general terms.

For instance, in comparing three-phase and single-phase line construction, it is utterly ridiculous to compare the cost of the New Haven construction with its very substantial bridges and double catenary suspension with that of the Simplon tunnel. If the simple construction of the latter, which is so light as to appear flimsy in the eyes of an American engineer, is safe for three-phase, it should be equally safe for single-phase. It is impossible to deny the fact that single-phase line construction is inherently much simpler, lighter and cheaper than that of three-phase. The light construction with direct suspension of the trolley wire, such as installed at the Simplon Tunnel, is apparently satisfactory for the slow and moderate speeds in use on all three-phase installations. If higher speeds were contemplated, catenary construction would be advisable if not absolutely necessary.

Again, in comparing the current collectors in use in this country with those in Europe, it must be remembered that the usual height of trolley wires in Europe is from 15 to 18 or 19 feet with small variations, while for all steam railways in this country it is 22 feet with large variations. The maximum speed on any electric system in Europe rarely exceeds 45 miles per hour, while 75 miles per hour is not infrequent in this country. The higher trolley wire and higher speed render the collection of current enormously more difficult and should be sufficient to explain the differences between American and European practice.

It has been customary to give the three-phase system the credit for all the advantages in light weight, due to the peculiar construction employing the Scotch yoke for connecting the motors to the driving wheels, and for the very light design of mechanical parts. The fact is that these features are not inherent with three-phase locomotives, but may be used to the same advantage with single-phase or direct-current locomotives. They have not been adopted in this country, because they have certain disadvantages which, in the eyes of American engineers, offset the advantages.

It has also been customary to credit the three-phase system with all the advantages of the simple control system in use on most of the three-phase locomotives. This is also a mistake, since if this control will meet the conditions of service satisfactorily with three-phase, the same type of control will give better operation with single-phase and will be cheaper, simpler and more efficient than when used with three-phase.

Further, in comparing the service capacities of different types of locomotives, it should be remembered that it is the *tractive effort* rather than the horse-power rating that determines the pulling power of a locomotive. For instance, it is customary to speak of the enormous horse-power rating of three-phase locomotives, and both direct-current and single-phase locomotives appear at a disadvantage with such a comparison. It must be remembered, however, that the rating of the three-phase locomotive is given at its maximum speed while the ratings of the single-phase and direct-current locomotives are usually given at less than half their maximum speeds. In service where the starting tractive efforts are much greater than those required for continuous operation, the horse-power ratings of three-phase locomotives will be much greater than those for direct-current or single-phase. For example, the 071 locomotive built for the New Haven road has a tractive effort for one hour of about 18 000 pounds. Its normal speed on level track is about 45 miles per hour, and it frequently reaches 50 miles per hour. A three-phase locomotive having these characteristics would be called a 2 400 horse-power locomotive, and yet it would have practically no greater service capacity than the 071 which is rated at 1 600 horse-power. In other words, the great difference in the speed characteristics of the different motors renders a comparison on the basis of the horse-power ratings utterly misleading—except where the locomotives are required to operate continuously at a certain tractive effort and speed. Under these

conditions a comparison on the basis of *continuous* horse-power rating will be correct.

In Europe the war of the systems goes merrily on. Italy seems to be pretty solid for three-phase, all the other countries except Switzerland, which is divided, are considering only single-phase. There are a few sporadic cases of high voltage direct-current, but they are not considered as serious.

The conclusions arrived at by the writer are:—

First, that systems can be compared only by eliminating all differences that are not inherent.

Second, that three-phase will give very satisfactory results where the speeds are uniform and low or moderate, and especially for work on heavy grades where the advantage of light weight is greatest, and the automatic regeneration of power serves to hold the train back in descending grades.

Third, that the single-phase system is able to meet practically any conditions of operation in general railway service, and that it is superior where a variety of speeds and especially high speeds are required and where the simpler overhead construction is especially desirable.

Fourth, that neither of the alternating-current systems would be necessary or desirable, if direct current at 600 volts could be collected from a distributing system, including sub-stations and contact conductors, as simple and cheap as that of the single-phase system.

N. W. Storer

The Electro-Chemical Society

Utilizing the materials and forces of nature is the province of the engineer. When either a new material or a new force is at his disposal, possibilities of a new order open new fields for research and for commercial application. Chemistry is the science which deals with materials. The chemist studies the fundamental construction of materials. He separates common substances into their constituent elements and devises new combinations with new properties. Electricity, on the other hand, deals with forces, the other fundamental factor lying within the province of the engineer. By applying his mysterious forces to the various fields of activity, the electrician has entered almost every department of modern life and industry with transforming effects.

Now a combination of these two fundamental and powerful sciences may reasonably be expected to produce still more marvelous

results; and so it is that electrochemistry, the combination of the science of materials and the science of forces, has given the investigator, the inventor, and the manufacturer a new and powerful means for securing results which were previously unattainable.

Electricity facilitates chemical action in three ways:—First, by means of the electric discharge or arc, as is exemplified in the manufacture of nitrogenous compounds from the air; second, by high temperatures, as in the manufacture of carborundum ore in the electric steel furnace; and, third, by electrolytic action as in the refining of copper.

The importance of a method of producing fertilizers for enriching the soil, making an ordinary commercial product of a metal previously rare in its elemental state, or the producing or refining of various metals and chemical products which enter directly or indirectly into modern industry, is self-evident. The processes of electrochemistry are usually dependent upon cheap electric power, and it is therefore only during a comparatively recent period that the industry has advanced. Its growth, however, has been rapid. It has been estimated that, if the electrochemical industries were brought together in one place, they would make an industrial center equal to that of Pittsburg. Their past history and the present activity give the highest promise of future extension and importance.

In the iron and steel industry the effect of the electric furnace will undoubtedly be far-reaching. In countries where fuel is dear and water-power abundant, as in Norway, the electric furnace is economically adapted for the making of pig iron. Under the conditions of at least moderately cheap fuel the electric furnace gives promise of being of immediate importance in the refining of steel; not merely for the production of steel of the present commercial qualities but of a higher grade of excellence, thereby giving, for general commercial use, a grade intermediate between the open-hearth and crucible products. There are at the present time a hundred iron and steel electric furnaces, a number of which are in America, and the active interest which is being taken, and the investigation which is now going on, may lead to great extensions in the near future.

The American Electrochemical Society is a vigorous and active organization having a membership of something over one thousand. The increase in membership in the past year has been thirty-seven percent. At the recent convention of the Society, held in Pittsburg,

there was a total enrollment of about four hundred and fifty, made up of the members of the Society and the engineers and manufacturers of Pittsburg who were guests. There were two hundred members of the Society in attendance, representing fourteen states and six foreign countries. This is a rather remarkable showing for a new society in a very specialized branch, which was organized only eight years ago. CHAS. F. SCOTT

Gasoline Motor Cars

Gasoline motor cars are often spoken of as substitutes for electric cars and they do appear to have a certain legitimate field. However, where there is sufficient business to warrant electrical equipment their use is not considered advisable. Most of the self-contained cars are equipped with gasoline engines, similar to but more powerful than automobile engines, while a few of them use small steam engines. Various methods of drive are employed to connect the engine to one or more of the car axles. In some cars the engine drives an axle through a chain or set of gears, as on automobiles; in others, known as gasoline-electric cars, the gasoline engine drives an electric generator which supplies current to electric motors geared to the axles. In another type of gasoline-electric car, a storage battery is carried to supplement the electric generator and equalize the load on the gasoline engine so as to supply extra power to the car motors at times of heavy demand. The various types of motor cars have had repeated trials and in many places have failed to give satisfactory results, but their failures have frequently been due to attempts to use them in competition with electric trolley cars where the latter were much better suited for the work to be done.

Wherever it is desired to operate single cars or trains at frequent intervals and to make frequent stops, self-contained motor cars have not been able to compete successfully with electric cars. The characteristics of the two kinds of motive power are entirely different. On interurban roads electric cars are usually equipped with motors having a total capacity of 300 to 500 horse-power and capable, for short intervals, of developing double this power, and the work they do demands these powers. Gasoline motor cars, on the contrary, usually have gasoline engines of from 100 to 200 horse-power and these engines have little or no overload capacity and in addition cannot use their full rated engine power at low speeds.

Gasoline cars have been successful in some places where infrequent service is required and where the stops are not too close together. There is not sufficient data available to state accurately their operating cost over long periods of use. It is certain that the fuel and maintenance cost will be much greater than the cost of electric power and maintenance for electric trolley cars. Gasoline engines when uniformly loaded take about one-tenth to one-eighth of a gallon of gasoline per brake horse-power-hour. At this rate and with gasoline at twelve cents per gallon, the cost of power would be from one and one-fourth to one and one-half cents per brake horse-power-hour but engines under the variable loads of motor car service cannot do nearly so well as this.

On branch lines of steam roads it is quite common practice for the train crew which is used to operate the infrequent passenger trains, to be used during idle hours for handling freight cars; and again a combination freight and passenger train is often the only service provided. In such cases the introduction of gasoline motor cars would hardly be considered seriously. Where gasoline cars are found to be profitable, sufficient traffic is very often soon developed to make electric operation more economical.

Obviously the field for gasoline motor cars is on tracks where only one or two or possibly three or four light single car trains are required per day each way. If high-powered cars or frequent service are required electric trolley car service will be more economical.

F. Darlington

Winding as a Mechanical Operation

The winding is the feature which distinguishes electrical apparatus from other classes of machinery. With the exception of the windings, all of the elements in the construction, maintenance and repair of a motor or generator are reducible to more or less simple mechanical operations. There are, of course, other points in the design of such machines which are of great importance from the electrical standpoint, such as the magnetic properties of castings and punchings, and the design of the commutator and brush-holder from the standpoint of satisfactory commutation, but to the men who build and to the men who operate motors, these questions are of little or no importance. These men have to do with the machines as mechanical pieces of apparatus, and as such they are similar to other machines with the exception of the windings. Superintendents and chief engineers of power

stations are often men whose training has been almost entirely along mechanical lines and, while well versed in the operation of steam machinery, they are at a loss to know what to do when troubles arise which affect the windings of their machines. Both the processes of manufacture and the methods of installation and repair are in a sense alien to such men, and when troubles occur which affect the windings of their machines they need the specialized knowledge of the experienced winder and electrical repairman to put their machines in good operating condition.

With the view of supplying, in a measure, this need of specialized knowledge to those who have occasionally to deal with the windings of electrical machinery, as well as to students seeking information regarding practical shop methods, a series of articles on armature windings and allied subjects has been prepared for publication in the JOURNAL. The articles are extremely practical and are based on up-to-date practice as found in a large electrical manufacturing company.

The initial plans for this series of articles were laid out by a mechanical engineer, Mr. R. A. Smart, now works manager of the Oliver Chilled Plow Works, formerly assistant manager of works of the Westinghouse Electric & Manufacturing Company. The material for this series has been obtained from a great variety of sources, and while each section has been prepared under the direction of a few men, the final result forms a composite of the ideas and experience of many experts in the manufacture of motors and generators, who have very kindly coöperated in the production of these articles, both by explaining the methods used in their particular lines of work and by checking the accuracy of the statements made. The series begins in this issue of the JOURNAL with a general introductory section, followed by a description of a method of winding a typical form of very small armature. In subsequent sections it is planned to publish illustrated articles on various types of windings for large as well as small machines, for induction motors, turbo-generators, etc. Parallel with these articles it is planned to present other articles of a more general nature in connection with the subject of this series, one of these being the article on "Impregnation of Coils with Solid Compounds" which has already been published in the March issue.

Practical men should find these articles of material assistance in acquiring definite knowledge of modern methods of winding various types of commercial machines.

INCANDESCENT WELDING

C. B. AUEL

INCANDESCENT or resistance welding is based upon the well-known principle that, in an electric circuit, resistance generates heat. There are two distinct processes of this kind in vogue, namely, the La Grange-Hoho and the Thomson.

In the La Grange-Hoho process, sometimes spoken of as the water-pail forge, Fig. 1, the metals to be welded or forged are fastened to the negative terminal of a direct-current circuit having a potential of 125 to 150 volts. The positive terminal which should be relatively large is immersed in an aqueous solution of

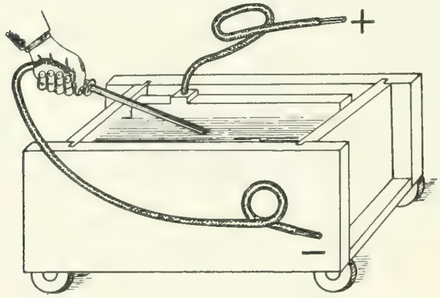


FIG. 1—THE LA GRANGE-HOHO WELDING PROCESS

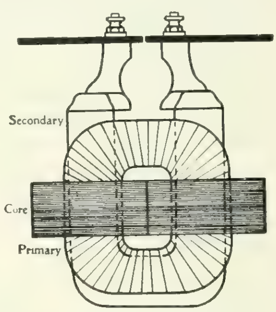


FIG. 2—THE THOMSON WELDING PROCESS

carbonate of potash (or soda) and borax in the proportion by weight of forty-four parts of the former to fifty-six parts of the latter, the specific gravity of the solution being 1.24. Upon completing the circuit by dipping the metals to be welded or forged into the solution, they are rapidly brought to the proper temperature and are then quickly withdrawn and welded together or forged to shape in the customary manner. This process has a rather limited application in that it is best adapted to small and simple work preferably of wrought iron and such as can be readily manipulated by hand. It may also be used at times to considerable advantage in heating soldering irons, bolts and rivets; and no less an authority than J. M. Gledhill, of Sir W. G. Armstrong, Whitworth & Company, has commented* favorably upon it for hardening lathe tools. He states that

*In a paper entitled "The Development and Use of High Speed Tool Steel," read before the Iron and Steel Institute (England).

"electric heating is quick, reliable and economical. The current is first switched on and then the tool is gently lowered into the solution to such a depth as is required to harden it. The act of dipping the tool into the alkaline solution completes the electric circuit and at once sets up intense heat in the immersed part. When it is seen that the tool is sufficiently heated the current is instantly switched off and the solution then serves to chill and harden the point of the tool, so that no air blast is necessary."

In the Thomson process, diagrammatically shown in Fig. 2, the parts to be welded are clamped to the terminals of a suitable alternating-current circuit and carefully butted together. When the circuit is completed, current flows through the abutting metals, heating them to fusion, after which they are automatically forced together, thus uniting perfectly. The resulting joint is accompanied by a shoulder or fin which is easily removed, usually by a hand file, though sometimes an automatic hammer or swage is employed. The apparatus, in general consists, of a transformer of from one to 100 kilowatts capacity or more depending upon the class of work to be done. The primary of the transformer may be designed for operation at any one of the usual voltages and frequencies (even 25 cycles may be used), the secondary being arranged to give a very large current, sometimes as much as 30 000 amperes, at voltages ranging from one-half to seven volts and being further provided with terminals in the shape of heavy clamps, sometimes water-cooled, in which are secured the metals to be welded. Variation of output is obtained by switches or by a choke coil in the primary circuit.

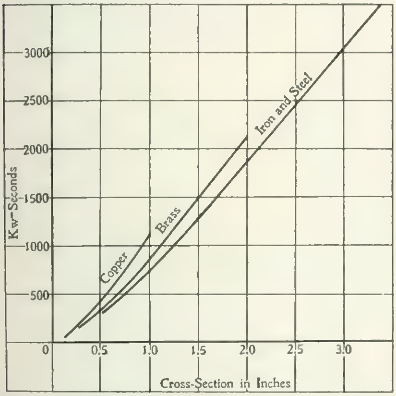


FIG. 3—POWER REQUIRED FOR ELECTRIC WELDING (*Thomson.*)

This process is employed for an almost indefinite number of purposes, such as uniting wires, rods or bars of similar or even of dissimilar metals, making tires and cylinders, putting heads on bolts and screw bodies, joining and bonding rails, welding links of chains, tying short lengths of wire or of strap together, joining pipe, etc. It is also used for annealing armor plate and certain kinds of cutting tools. There is no doubt but that it meets every

requirement in the making of the ideal weld. The heating is developed quickly or slowly as desired and from the center outwardly; it is, moreover, confined to the immediate vicinity of the joint. The flow of current is under the control of the operator during the process and may be so arranged as to be cut off by means of an automatic device at the instant of completing the weld. The danger of burning the material is therefore quite remote and no waste of energy occurs. As the range of temperature is limited only by the fusion point, practically all metals can be welded; and many different ones as, for example, iron and brass, can be united to each other. Since there is no contact with any uncertain substance such as coal or coke and since flux is seldom required as in the blacksmith-made weld, the structure of the metals undergoes no change from this source and the strength of the weld may be taken as nearly the same as that of the original stock; likewise, the electrical conductivity of the metal is found to be unimpaired.

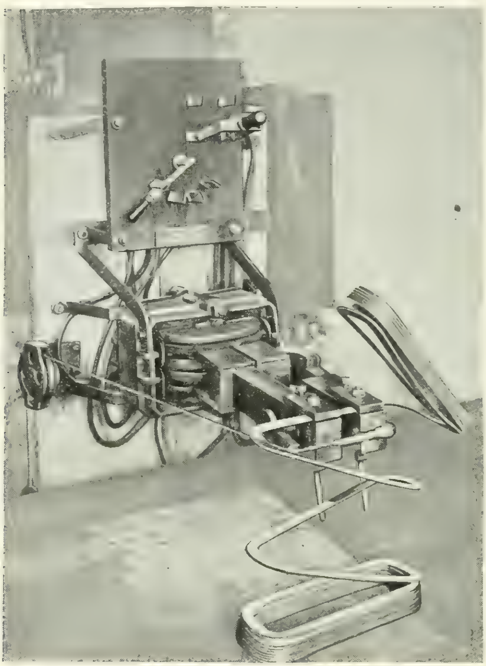


FIG. 4—ELECTRIC WELDER FOR STRAP COPPER
Westinghouse Electric and Manufacturing Co.

The energy required in welding by this process is dependent upon several factors, namely, the electrical and the thermal conductivity of the metal, the length and the cross-section, the general shape, the fusing temperature, the time consumed in making the weld, etc. The curves given in Fig. 3 have been prepared from data published by Prof. Elihu Thomson and show the approximate energy in kilowatt-seconds necessary for welding iron,

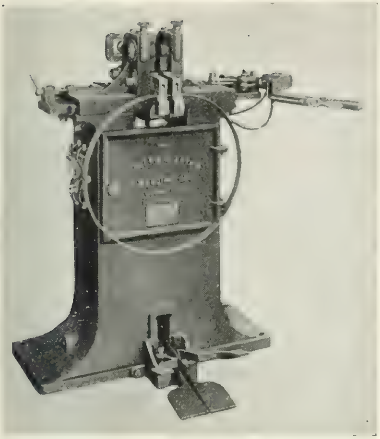


FIG. 5—ELECTRIC WELDER FOR CARRIAGE TIRES
Toledo Electric Welding Co.

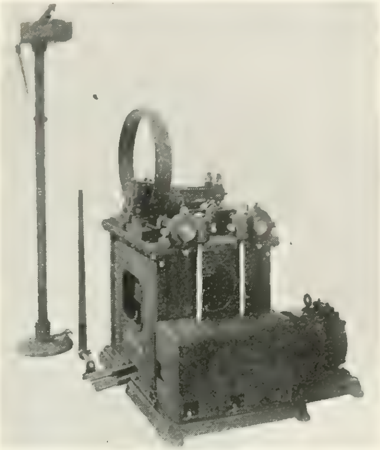


FIG. 6—ELECTRIC WELDER FOR AUTOMOBILE TIRES
Toledo Electric Welding Co.

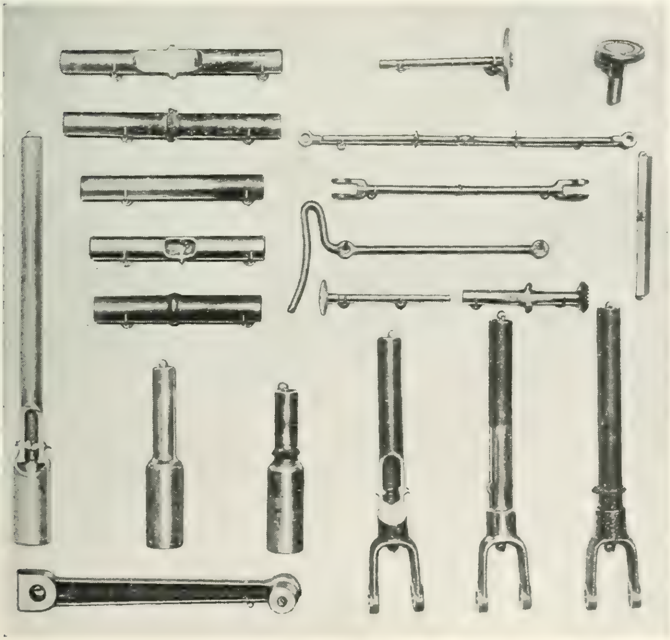


FIG. 7—COMPLETED WELDS
Made in Toledo Electric Welding Machines.

steel, brass and copper bars. As Prof. Thomson says: "It will be seen that the energy increases more rapidly than the section of the pieces, doubtless because the large pieces take a longer time in welding, with the result of an increased loss by conduction of heat along the bars from the joint. If the time for welding could be made the same for various sections it is probable that the energy required would be more nearly in direct proportion to the area of section for any given metal. This rule would hold, however, only approximately as there is a greater relative loss of heating by radiation and convection into the air from the pieces of smaller section."

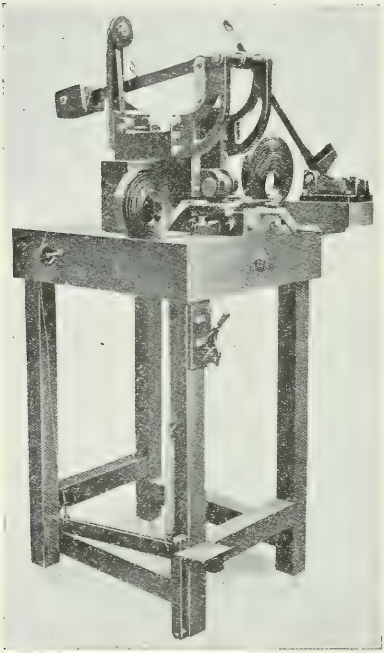


FIG. 8—ELECTRIC WELDER FOR STEEL TAPE
British Insulated and Helsby Cables.

Considering a few typical examples of welding machines, Fig. 4 shows a very simple design made by the Westinghouse Electric & Manufacturing Company. It is of two kilowatts capacity, having a range sufficient to handle copper wire (or the equivalent) both round and square from No. 12 (0.109 inch) to No. 2 (0.265 inch) B. & S. gauge.

A machine made by the Toledo Electric Welding Company, similar to the preceding, but of considerably greater capacity, is shown in Fig. 5. The pieces to be welded are placed in the copper jaws, being butted together and held in position by the clamps which are operated by the larger of the two pairs of foot-treadles. Current is turned on and off in the primary circuit by the spring thumb-latch attached to the lever at the right. When the welding temperature is reached, this lever is pulled towards the operator, thus forcing together the two pieces or ends of the material and thereby completing the weld. The piece is then released by means of the smaller of the two pairs of foot-treadles.

Fig. 6 is a machine particularly adapted for automobile tires up to 5.5 by 0.375-inch in section. The ends of the tire are forced together by the motor-operated screws shown at the right. The circuit is closed by the switch mounted on the pedestal, through the medium of the lever at the left. Some of the welding products of the machines of this company are shown in Fig. 7.

Figs. 8 and 9 show machines made by the British Insulated & Helsby Cables, the former for welding steel tape or ribbon (3 by 0.015 to 0.0625-inch), the latter for welding iron chain (0.3

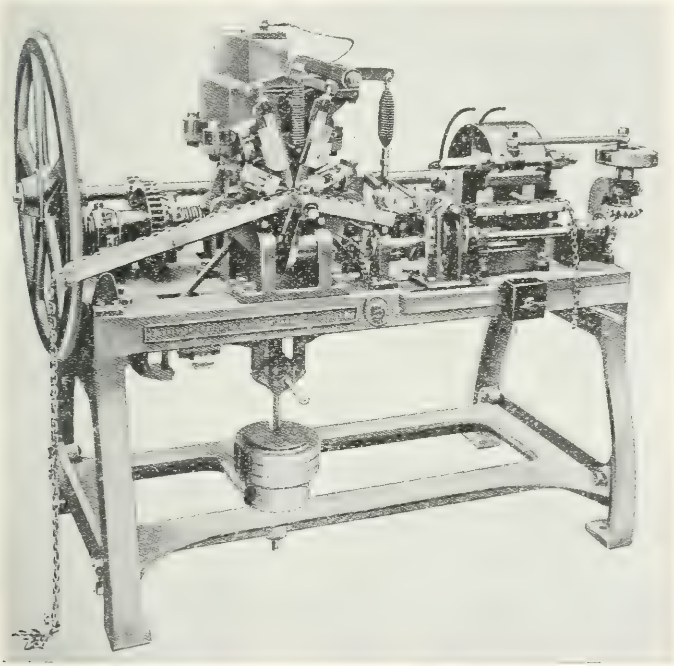


FIG. 9—ELECTRIC CHAIN WELDER
British Insulated and Helsby Cables

inch diameter), 10 to 12 links being welded per minute. The chain-welding machine is automatic, the unwelded chain being fed through the trough on the left to the welding electrodes, at which point each link is gripped in suitable jaws and the electrodes are at once brought into contact with the link, one on either side of the joint. Current then flows through the link, passing in large measure through the portion between the electrodes, quickly softening that part of it. The weights, which are

suspended on a toggle-lever, then come into action, forcing the softened ends of the link together and forming the solid link.

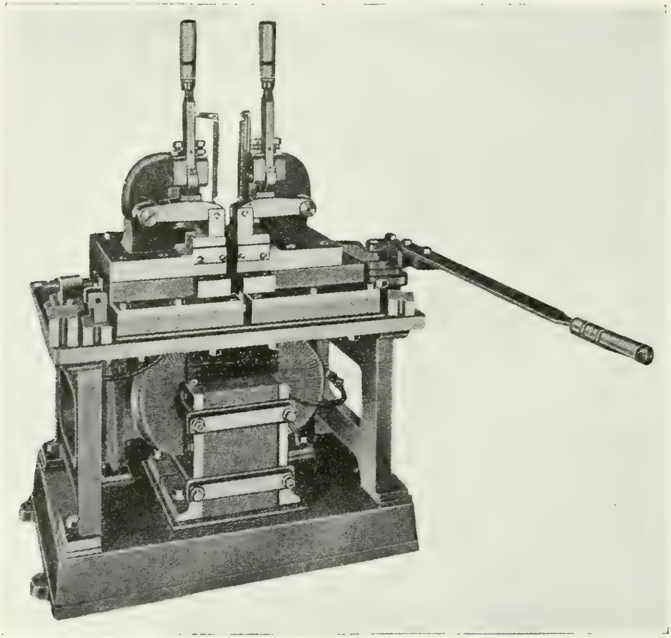


FIG. 10—ELECTRIC WELDER FOR CARRIAGE TIRES
Thomson Electric Welding Co.

Current is next shut off and swaging levers close over the weld, compressing the metal and thus ensuring a perfect union. Only

TABLE I—DIMENSIONS OF WELDING MACHINES
THOMSON ELECTRIC WELDING CO.

Machine.				Max. Weldable Area	
Weight Lbs.	Length Inches	Width Inches	Capacity Kw	Iron Sq. In.	Copper Sq. In.
125	13	12	1	0.05	...
525	27	15	5	0.30	0.11
2 200	54	30	20	1.23	0.40
7 000	90	36	40	3.00	0.79

alternate links are welded, so that it becomes necessary to pass a chain twice through the machine before it is completely welded.

Fig. 10 is a machine designed by the Thomson Electric Welding Company for welding carriage tires and similar work up to 1.25 by 0.375 inches in cross-section. The front cover has been removed, showing the transformer in position underneath. In Fig. 11, which shows several welds made by this company's machines, the slight

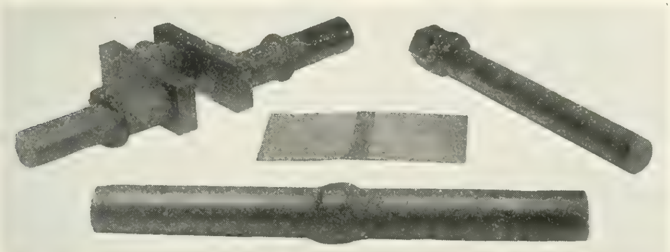


FIG. 11—COMPLETED WELDS
Made in Thomson Electric Welding Machines.

boss, previously referred to as being found at the weld may be clearly seen.

A machine made by the same company, for use in spot or point welding, that is for welding metal at isolated spots, as applied to thin sheets, is illustrated in Fig. 12. These sheets are first indented,

TABLE II.—CURRENT COST OF ELECTRICALLY WELDED BUTT JOINTS—IRON AND STEEL

CURRENT TAKEN AT ONE-HALF CENT PER KILOWATT-HOUR

Area Sq. In.	Cost Per 1000
0.10	$0.058
0.22	0.122
0.45	0.369
1.00	1.17
1.50	2.02
2.00	2.96
3.00	4.77
4.00	7.06

as shown in Fig. 13, on a separate machine, after which they are over-lapped and clamped in the welder. Current is then sent through the contacts and either a part or all of the welds made at once. Wire mesh for fence or for reinforced concrete work may also be made in this manner.

Table I, taken from data published by the Thomson Electric

Welding Company, will afford an idea of the relative dimensions, weights and capacities of their machines.

It is exceedingly difficult to give reliable data on the cost of incandescent welding owing to the variables involved. The number of welds capable of being made per day may vary from 100 to 200 for heavy or difficult work to 7 000 or 8 000 for light or automatic work. In some classes of work, the set-up time may be greater than the welding time, while in others the reverse is true. In repetition work, for example, the set-up time for small sections will usually be the greater, while for large sections it will generally be the lesser. In miscellaneous work the set-up time will almost always exceed the welding time. Again, some manufacturers of welding apparatus install their machines free, simply charging a small royalty on each weld made, giving the welder to the purchaser without further cost at the end of a certain period; other manufacturers sell their machines outright. Further, as already pointed out, the energy consumed is, among other things, dependent upon the rapidity with which the welding is done, the larger pieces requiring the greater expenditure. The current cost can, however, be closely approximated and is given in Table II, current being priced

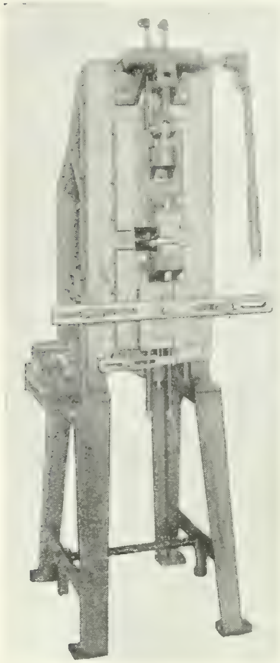


FIG. 12—MACHINE FOR SPOT WELDING OF METAL SHEETS
Thomson Electric Welding Co.

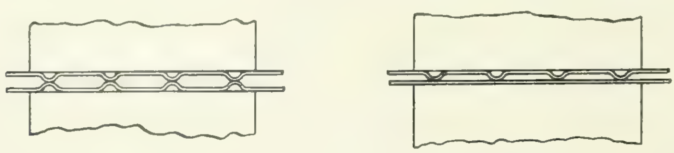


FIG. 13—SPOT WELDING OF METAL SHEETS
Showing the sheets of metal clamped in the jaws of the welding machine.

at one-half cent per kilowatt-hour. Table III shows some very interesting figures of the comparative costs of welded versus soldered stator coils of the "shove-through" type. It will be noticed

that while the labor is practically the same in the two cases, there is a considerable saving in the material when the coils are welded instead of soldered.

In the annealing of armor plate and machine tools the principle involved is the same as in welding, but the application is slightly different. Fig. 14 shows a machine for the local annealing of armor plate, made by the Thomson Electric Welding Company. In this apparatus the secondary of the transformer is hollow and is so arranged as to include the primary; it is moreover filled with oil which has the double function of an insulating as well as of a cooling medium, although water is used in addition

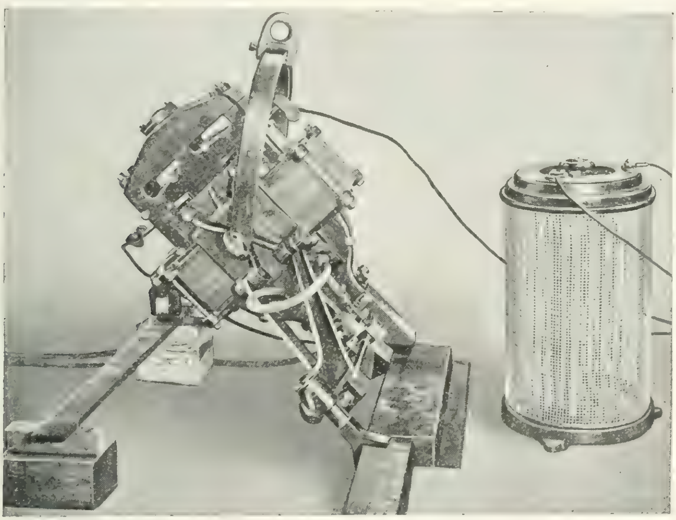


FIG. 14—ELECTRICAL ANNEALING OF ARMOR PLATE
Thomson Electric Welding Co.

for the latter purpose. When annealing a spot, the secondary terminals are first brought into contact with the armor plate, current is then gradually turned on, being increased until the proper degree of heat has been obtained, after which it is as gradually decreased to zero. In this way, re-hardening of the annealed spot is prevented, which would otherwise occur were the current to be suddenly turned off. This scheme has been followed by most of the armor plate manufacturers and builders of warships, both in this country and abroad, in preparing armor plate for such machining operations as drilling holes, cutting ports in turrets, etc. It will no doubt be largely superseded in

due course by the oxy-acetylene burning and cutting-off process.

Fig. 15 shows clearly the method outlined by J. M. Gledhill in the paper previously referred to, when applied to the annealing of milling and gear cutters, hollow taps, reamers and other hollow high speed tools and where as stated "it is required to

TABLE III—SOLDERED VERSUS ELECTRICALLY WELDED JOINTS

Sizes of Wire	Total Connections	Soldering		Electric Welding Flat Labor
		Flat Labor	Material	
0.102"x0.175"	1 008	$73.92	$ 5 52	$71.68
0.289"x0.289"	450	68.32	13.88	64.96
0.080"x0.175"	1 008	86.80	5.22	85.68
0.129"x0.210"	637	60.48	8.12	60.48

Labor = 28 cents per hour.
Copper = 20 cents per pound.
Solder = 16 cents per pound.
Neither current nor gas taken into consideration.

have the outside or cutting portion hard and the interior soft and tenacious, so as to be in the best condition to resist the great stresses put upon the tool by the resistance of the metal being cut and which stresses tend to cause disruption of the cutter if the hardening extends too deep."

Great success has been met with in the welding of street car rails by the incandescent process. The apparatus developed by the Lorain Steel Company for this purpose consists of four cars, Fig. 16, the first containing a motor driven air compressor and sand blast, Fig. 17, the second and third a rotary converter, a static transformer, a combined welder and hydraulic grip, also a water cooling system, Fig. 18, and the fourth a motor-driven grinding wheel operating through a belt, Fig. 19. Direct current is taken from the trolley, being changed before use to alternating current of the proper voltage by means of the rotary converter and the static transformer just mentioned. In making a weld the abutting rails are first securely spiked into position

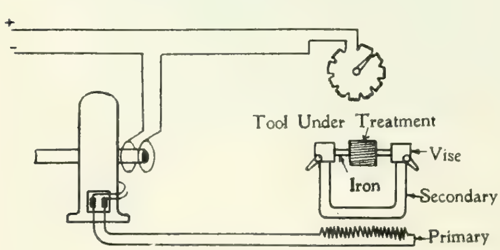


FIG. 15—METHOD USED IN THE ELECTRIC ANNEALING OF MILLING AND GEAR CUTTERS, ETC.

FIG. 16—ELECTRIC TRACK WELDING EQUIPMENT
Lorain Steel Co.

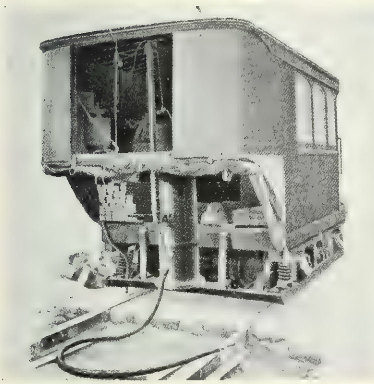


FIG. 17—SAND BLAST EQUIPMENT

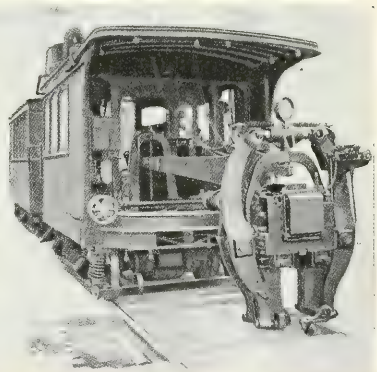


FIG. 18—WELDING EQUIPMENT

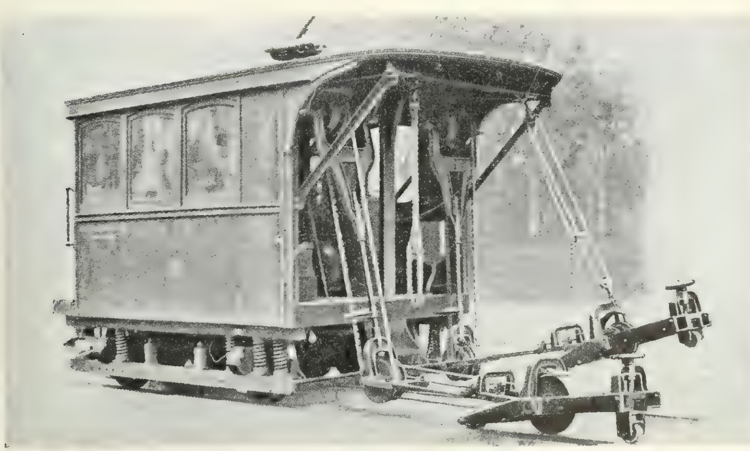


FIG. 19—GRINDING EQUIPMENT

after which they are cleaned in the vicinity of the joints by means of the sand blast. Heavy wrought iron plates, one and one-eighth inch thick, Figs. 20 and 21, are then placed on both sides of the rail and straddling the joint, being held in position by the hydraulic grip under a pressure of about 1 000 lbs. per sq. in. The plates are provided with bosses *B* on each end and with a strap *A* at the center, which bear against the web of the rail when the plates are in place. The projections, by making contact between the plates and the rail, confine the current to the portion to be heated, thus enabling a welding heat to be attained. These end projections are formed by means of a die, the depression being afterwards filled in with a piece of metal. The center projection is made rather differently by the strap *A* as shown, for were this projection to be made the same as those at the ends, the plates would be weakened in the middle just where the greatest strength is required. Approximately 30 000 amperes at from five to seven volts are required and the area heated is about 3.5 square inches. In making a weld, flux is used and as the fusing temperature is approached the pressure of the hydraulic grip is increased to 4 000 pounds per square inch, and the weld completed. Additional welds are made on both sides of the original giving a total of three to each joint. The terminals of the grip are of copper and are renewable.

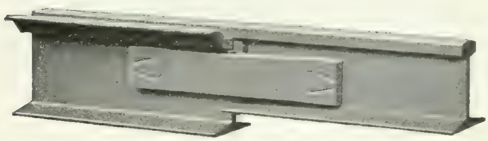


FIG. 20—WELDED RAIL JOINT

Showing rails of different sections welded together.

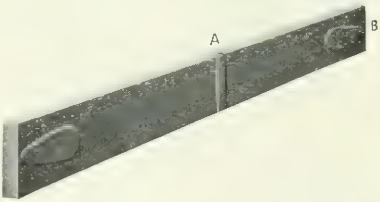


FIG. 21—WROUGHT IRON PLATE USED IN RAIL WELDING

The welds are made at the points of contact of the rail with the strap *A* and the bosses *B*.

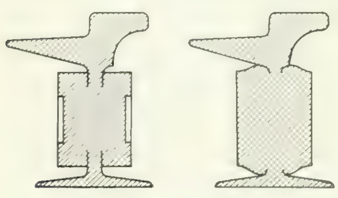


FIG. 22—WELDED RAIL JOINT

The figure at the right shows a section at the center of the joint, through the strap *A*.—The figure at the left shows a section through the boss *B*.

About fifteen minutes are consumed in the making of a complete joint, this including the three welds; the actual time during which the current is turned on is from two to three minutes per weld.

Six men are required to operate an equipment of this kind and eighty welds is not an unusual number per day of twenty-four hours. By means of the grinder, the rail is then smoothed down. Fig. 22 shows vertical sections of a welded joint.

Mr. R. H. Rice, assistant engineer of the Board of Supervising Engineers, Chicago Traction, states that "the breakage of electrically welded rails is considerably under two percent, the break never occurring at the weld itself but from eight to twelve

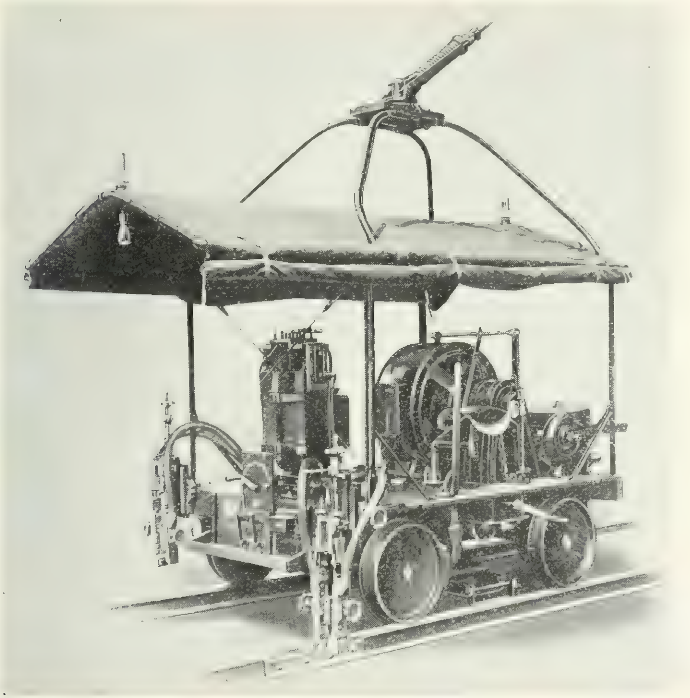


FIG. 23—ELECTRIC RAIL BONDING CAR
Electric Railway Improvement Co.

inches away, or at the edge of a heated zone. Experience seems to indicate that the welded rails must be buried in the pavement and not left permanently open, even on one side." As showing the existence of tremendous stresses an instance is on record of a rail breaking when being sawed in two, the ends separating about 1.5 inch; regardless of such fact, however, the rails keep their alignment.

A somewhat similar application of this same process but on

a smaller scale is the rail bonding car shown in Fig. 23. The grip, detailed in Fig. 24, instead of having both terminals of copper as is the usual custom, has one terminal of copper and one of carbon, Fig. 25, the former pressing against the rail. In bonding, about 2 000 amperes at five volts are required for 45 to 120 seconds, depending on conditions. The operating force consists of three men, and 100 bonds per day of twelve hours may readily be installed. Fig. 26 shows an electrically welded bond as applied to a third rail.

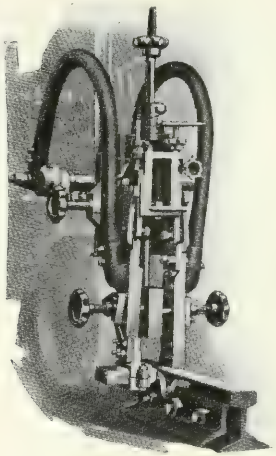


FIG. 24—DETAIL VIEW OF GRIP USED ON RAIL BONDING CAR

Perhaps the most elaborate welding apparatus of this kind yet built is that installed in the works of the John Wood Mfg. Company, Conshohocken, Pa., for the welding of steel bath and kitchen boilers. The machine is nine feet high, six feet wide and twenty feet long. Fig. 27 shows a boiler in process of welding. As will be seen, the transformer is located at the top, the secondary extending downwards, its terminals ending in two large copper discs about 26 inches in diameter and 1.25-inch thick, free to revolve in gun-metal bearings and being insulated from the framework of the machine. The shell of the boiler is first lifted into position by inserting one end into the yoke, with the split uppermost, a small thin blade on the yoke keeping the seam in exact alignment with the discs. A "come-along" operated by an endless chain grips the shell and pulls it through the yoke, under the discs and beyond them. Two pressure rolls *A* force the edges together. The welding commences as soon as the shell

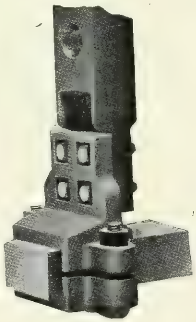


FIG. 25—CARBON ELECTRODE SHOWN IN FIG. 24

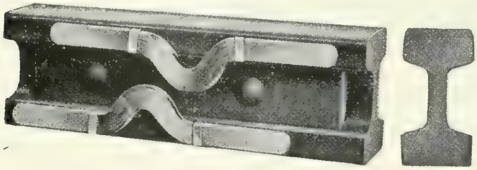


FIG. 26—ELECTRICALLY WELDED BOND ON THIRD RAIL

strikes the discs and continues for about 20 seconds, when the operation is completed, the shell having traveled its length of from 5 to 6 feet in the interim. About 30 000 amps. at 2.5 to 4.5 volts are required for welding and the seam is heated but a fraction of an inch on either side. One minute elapses from the time a shell is picked up at one end of the machine to the time it is set down at the other end. A half-round bead is formed at the seam

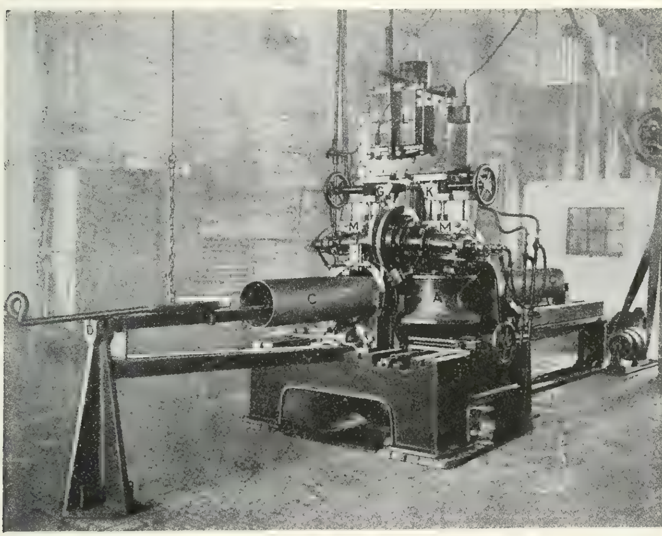
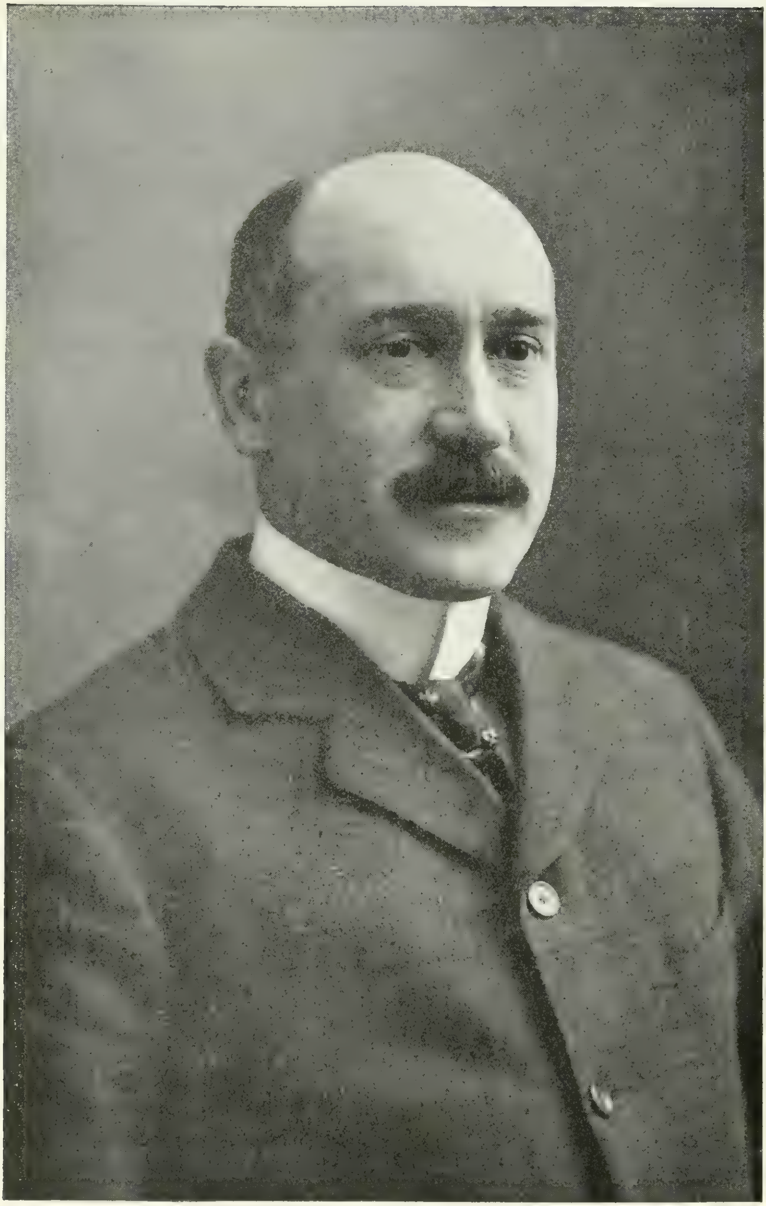


FIG. 27—APPARATUS FOR THE ELECTRIC WELDING OF STEEL BOILERS
Standard Welding Co.*

which is later removed and the shell made truly round by passing through a pair of rollers. The thickness of the plates thus welded will range from No. 16 (0.065 inch) to No. 9 (0.148 inch) B. W. G. and the finished boilers are regularly tested at 175 and 200 pounds pressure.

In conclusion it may be stated that incandescent welding occupies a field of its own quite apart from that of arc welding or of oxy-acetylene welding and one which cannot be infringed upon with advantage by either; in fact, all three processes may be said to be complementary rather than antagonistic.

Illustration by courtesy of *American Machinist*.



WALTER CRAIG KERR

WALTER CRAIG KERR

AN APPRECIATION

E. H. SNIFFIN

IT is not easy to write when the heart is sad. When a close friend is taken from us we feel more comfort in silence. And perhaps, too, it were better that we wait awhile if we would record in calmer terms, and with more contemplative judgment, a truly proportional estimate of his worth. But Walter C. Kerr, whose death recently saddened a host of friends, was a prominent man, known in many circles, identified with many achievements. And it would seem that the JOURNAL, of which he thought highly, in which his luminous articles occasionally appeared, and whose readers were so well acquainted with the man and his work, should in this early number present a somewhat intimate view of this fine, able, lovable personality as his friends knew him. We may not know the Divine purpose which removes from us at scarcely over fifty, a life from which flowed so much good, but we may and do know that the beneficent influences of that life will be nurtured and carried on by a great number whom he inspired by what he did and said. For Mr. Kerr was a great doer of things. He embodied in a singular degree the spirit of performance. He was a very active, purposeful man, who struck at fundamentals, eschewing non-essentials, seldom missing the true line between cause and effect. Being a creator, he traveled a wide sea, but always over a well-charted course. Usually a man so identified with actual achievements is given to reticence. We generally find one class of men who actually do things, and another kind more given to theorizing than to performing. Mr. Kerr possessed the quality of always doing, always producing something; and also, though his analytical turn of mind and philosophical habit of thought, together with unusual facility of expression, the ability to impart to others the fruit of his reasoning. In his later years, his occasional lectures, usually before student bodies, his theme pitched to the motives of his own work, brought him before the public mind as an exemplar and teacher of sound business and engineering principles. Business and engineering were the two subjects inseparably linked in his life's work. He saw the economic necessity of new methods which would achieve a truer relation between the two, where the engineer was brought to the exercise of his real function, and where good engi-

neering became a synonymous term with good business. It will be interesting to know something of how his ideas on this subject matured. Perhaps we might first consider how they started.

Born in Minnesota shortly before the Civil War, we find him at the age of twelve shingling roofs and tacking on laths, as yet to get his first sight of a railroad. At sixteen he was running a transit, drawing a man's pay. He himself thought that environment was not a force. It was not difficult, though, to discern in the man of later years, with his broad culture and refined tastes, the signs of early closeness to the earth, manifested for one thing by his manual dexterity, but chiefly by that full-eyed candor and truth-dealing habit which a true man absorbs from nature. He goes to Cornell, graduating in '79. Remaining there for awhile, first as instructor, then as assistant professor, he enters business in 1883 as a salesman for The Westinghouse Machine Company. A year later he is one of the organizers of Westinghouse, Church, Kerr & Company, first holding the office of treasurer, then vice-president, and later—some fifteen years ago—becoming president. For many years that company was selling agent of the Machine Company, and for a few years also of the old Westinghouse Electric Company. Besides selling the products of these companies, they also took contracts for complete plants, until that became the chief part of their work. His entrance upon commercial engineering work was contemporaneous with the introduction of electricity for public use. Engineering practice was woefully crude and power plants were very wasteful of fuel. In his then selling and contracting business Mr. Kerr employed the best known engineering methods, and much of the early success of the Westinghouse product was due to the good conditions surrounding its application. A commercial business—that of selling and erecting machinery—gradually acquired a strong engineering complexion, and the concern often received contracts because of the engineering integrity of its work rather than because of the machinery it sold.

In about the middle nineties, Mr. Kerr began to formulate his ideas of engineering service. He foresaw the approaching era of vast public improvements which would call for the creation of great utilities involving many branches of engineering knowledge. He felt that such projects would have to be handled in their entirety, from contemplation to execution, without artificial divisions to harbor hazard and prevent a true correlation of these many branches into a harmonious whole. He believed strongly that the perform-

ance of such work should be carried on in the unselfish spirit of engineering service, unhampered by any idea of speculative gain, the compensation to be small but certain; that there should be absolute community of interest between property owner and property creator. It was the master and servant principle *a priori,* under which large and difficult work could be handled by a simple and effective relationship. It was the characteristic of the man, plain and true himself, to see the full application of a plain principle.

His genius for organization now came into play, and he began the work which chiefly marked his life success. His whole conception of engineering work was founded on organized, coöperative effort. He believed in individuality; no man ever did more to encourage it. He had a way of giving to a subordinate authority and responsibility in such measure that one soon rose to his fullest powers. But he understood, too, the limitations of the one man. He felt there were some men of but ordinary capacity, who on their own resource performing with small success, might in an organization contribute much good. He also held strong views respecting certain other men who had worked alone successfully, and sometimes brilliantly, but were by temperament and habit wholly unfitted for coöperative effort. He had an unerring sense of fitting men together. He believed that they should be selected with care, then taken as they were, without trying to remake them, but rather to develop what they had to the fullest use. He reposed great confidence in his men. He respected them in a manner to compel their own fullest self-respect. There never could be in any organization of men a greater absence of personal differences than existed in the atmosphere of Mr. Kerr's leadership. He was in the highest degree an organization man, around whom men worked with an *esprit de corps* and mutuality of purpose which only a real organizer could inspire. Such an organization was indeed essential to the success of his theory. It was necessarily of slow growth and required to be a large aggregation of engineers variously specialized in different branches of work, as well as architects, chemists, statistical experts; in fact, all the organized talent which could handle any work from beginning to end.

We sometimes think that business and sentiment are wide apart. In point of fact, business is a human relationship, and if the judgment of men had always been divorced from their emotions, many of their great material successes had never been achiev-

ed. Mr. Kerr was proud of his organization. Not only that it prospered materially, but that it stood for correct methods of doing work. He was able to see the fruition of his ideas in work done. Great undertakings, totaling vast sums of money, have been accomplished by his methods. It is the only large engineering organization to-day which by its engineering work alone, without financing departments or property-controlling adjuncts, has thrived and grown. He may well be regarded as the leading constructive engineer of his time.

Mr. Kerr was a man of most engaging personal qualities. First of all, a man of affairs, closely identified with business more than a quarter of a century, he had none of the narrowness so commonly observed in men whose business absorbs them. He was for twenty years a trustee of Cornell University, and exerted a strong influence on educational work. He believed in the democracy of education; that it was an essential thing to have, and it mattered little how it was obtained; that a man only had education when he could use it—a world of wisdom in that.

He was a man of wide knowledge, and technically versed in many special subjects. His mental recreation carried him to the study of minerals, of insects and of plant life, in which his fondness for the microscope found full play. For his real fun he followed yachting. A member of the Seawanhaka-Corinthian and New York Yacht Clubs, he was on the regatta committee of both. Some used to think that he worked at yachting, instead of playing. But it was in the man's nature to produce something even at his play.

Many years ago he did some research work on the tides of New York Harbor, preparing charts which came into great demand. His technical knowledge of the subject and facility at mathematics created a natural demand for his service on these working yacht club committees. He was a member of many technical and scientific societies, and of numerous clubs. He was recently elected vice president of the Merchants' Association of New York.

Such a man it was who for twenty-five years or more identified himself with the Westinghouse interests; who rendered to his work all that he had; who made his success not alone, but joined with others in organization achievement. A man of high ideals, of unswerving loyalty to his fellows, of great, noble character.

WINDING OF DYNAMO-ELECTRIC MACHINES—I

INTRODUCTORY

R. A. SMART

THE laying out of a given type of winding for a generator or motor so that it will develop current of the desired voltage or phase, is a problem quite as much of geometry as of electrical engineering, when once the underlying principles have been mastered. After a satisfactory general arrangement for the winding has been determined, consideration must be given to the mechanical details and to the problem of obtaining the desired results with a minimum amount of copper or placing the copper in a minimum space, and of so arranging the connecting portions of the winding, which are outside of the magnetic field, that they will be of relatively simple shape and fit together without interfering with each other. The voltage to be generated, the number of coils per slot, the number of slots per pole or per phase and their shape, all have their effect in determining the nature of the coil to be employed, and must be decided before the actual work of laying out the coil is begun.

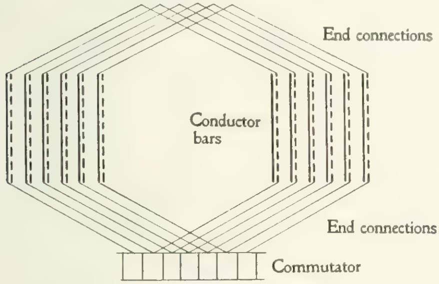


FIG. 1—SHAPE OF COILS FOR LAP WINDING

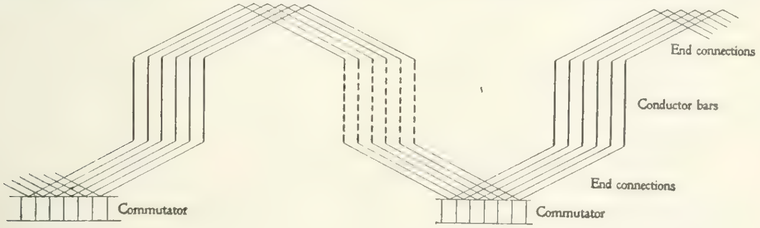


FIG. 2—SHAPE OF COILS FOR WAVE WINDING

DIFFERENCE BETWEEN ALTERNATING-CURRENT AND DIRECT-CURRENT WINDINGS

The characteristic difference between alternating-current and direct-current armature windings is that the former are generally wound on the stationary part of the machine, while the latter are wound on the rotor. Obviously the simplest method of collecting

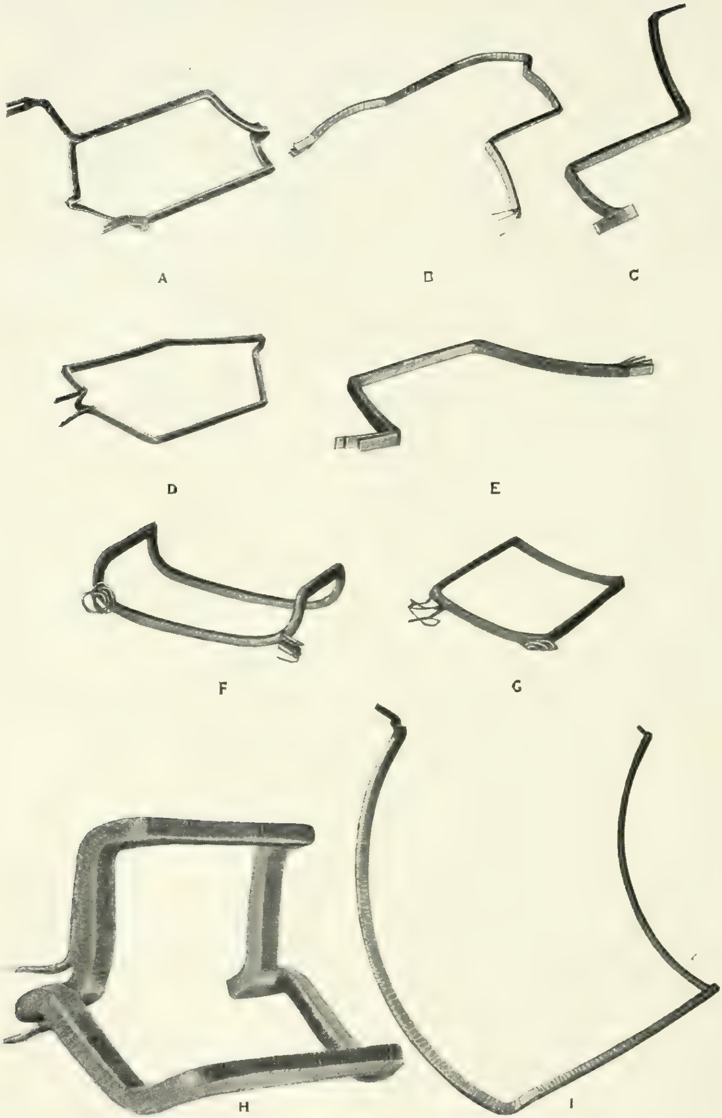


FIG. 3

A—One piece series diamond strap coil. Leads at end of straight part. *B*—One piece series diamond coil. Leads at end of straight part. *C*—Two piece series diamond coil. *D*—One piece multiple diamond coil. Leads at point of diamond. *E*—Two piece multiple diamond coil. *F*—Concentric coil—bent down at both ends. *G*—Concentric coil—straight. *H*—One piece wire wound involute coil. Leads at point of involute. *I*—Two piece involute coil. Leads at point of involute.

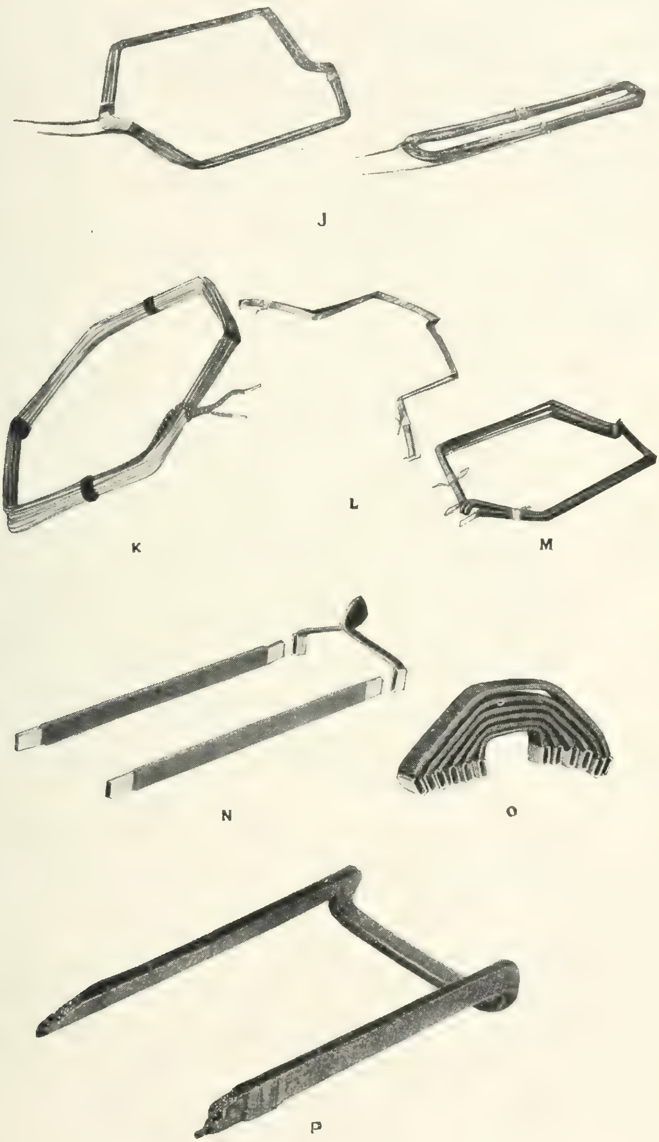


FIG. 3

J—Threaded in type diamond coil. Leads at point of diamond before and after pulling. *K*—Basket coil. *L*—Same as *B*—Threaded in type. *M*—Same as *D*—Threaded in type. *N*—Bar and involute end connector. *O*—Group of concentric end connectors. *P*—Concentric shoved through type coil bent down on one end.

current is from a stationary winding, thus obviating the necessity for using sliding contacts. The slip rings on an alternator convey a small current to the field magnets, but the main generated current is taken from the stationary armature. An induction motor is very readily supplied with a large current; only on starting is it ordinarily necessary to use a current collecting device in connection with the rotor. But a direct-current machine or a rotary converter presents a different problem, for not only must the current be collected from the armature winding, but the alternating-current which circulates in the windings must be changed to direct-current

TABLE I.—CLASSIFICATION SHOWING TYPES OF ARMATURE WINDINGS

Mould Wound Coil:—Insulated Wire or Ribbon	Open Slots	Diamond		Leads at ends of straight part
				Leads at point of diamond
		Involute		Leads at ends of straight part
				Leads at point of involute
		Short Type Involute		Leads at point of involute
		Concentric		Straight
				Bent at both ends
	Partially Closed Slots	Shoved Through Concentric		Straight
				Bent at one end
				Bent at both ends
		Threaded	Diamond	Leads at ends of straight part
				Leads at point of diamond
			Shuttle	Leads at ends of straight part
			Basket	Leads at point of diamond
		Hand-Wound, Pulled Through Concentric		Straight
				Bent at one end
				Bent at both ends
Former Wound Coil:—Bare Wire or Strap	Open Slots	Diamond		Leads at ends of straight part
				Leads at point of diamond
		Involute		Leads at ends of straight part
				Leads at point of involute
		Concentric		Straight
				Bent at both ends
	Partially Closed Slots	Shoved Through Concentric		Straight
				Bent at one end
		Threaded	Diamond	Leads at ends of straight part
				Leads at point of diamond
Bars and Connectors:—Bare Strap	Partially Closed Slots	Involute End Connectors		
		Concentric End Connectors		

by some form of commutating device. The revolving armature with the windings connected to the commutator bars affords the most satisfactory solution of the problem that has yet been presented.

THE PRINCIPLE FORMS OF COILS EMPLOYED

The windings used in revolving armatures of direct-current machines and in the stationary armatures of alternating-current machines may be divided roughly into two classes, known as multiple or lap windings and series, two-circuit or wave windings. The former may again be divided into progressive and retrogressive windings. The characteristic shape of coils for lap wound and for wave wound armatures, is shown in Figs. 1 and 2. A classification of various

kinds of windings is given in Table I. The designations employed in this table are those in use by the authors, and it is possible that similar coils used elsewhere are known by different names. The first division depends upon the material from which the coil is made, whether of wire, strap or bar copper. The second refers to the character of the slot, whether open or partially closed, and the third represents the great variety of shapes and forms which adapt the coils to the particular purposes for which they are intended.

In Fig. 3 are shown some of the principal forms of coils mentioned in Table I. Each of these general forms has many variations, depending upon the material from which it is made and the

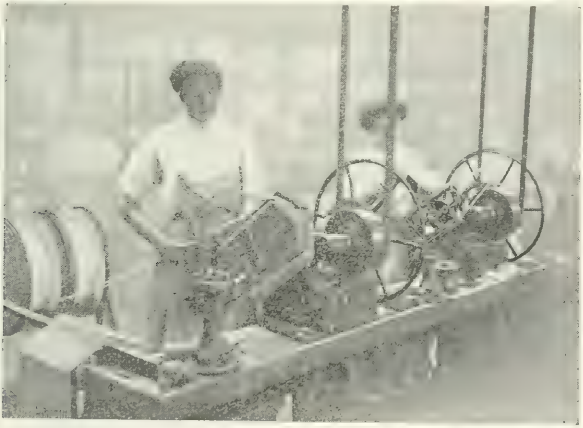


FIG 4—WINDING COILS ON MOULDS

The mould is in two parts. The wire is wound on under tension and is bent into shape with a mallet and drift.

characteristics of the winding of which it is to form a part. In general, wire-wound coils are made over a mould which is swung in a winding lathe, such as illustrated in Fig. 4. Coils of strap copper are formed over a stationary wooden or iron former, such as shown in Fig. 5.

The general characteristics of the different coils in general use may be stated as follows:—

Diamond Coils—The diamond coils, when completely insulated before they are inserted in the armature, can be used in open slots only. Their great advantage is the easy and simple manner in which they can be manufactured, especially in large quantities, which makes them well adapted for standard machines. Since all the coils used on

one machine are of the same size and shape, only one winding mould over which to form them is necessary. Moreover, the number of spare parts which must be kept on hand for repairing is reduced and repairs can be made easily and quickly. From the electrical point of view, the diamond type of winding possesses the advantage of being absolutely symmetrical. Hence there is no tendency for unbalancing of voltages due to differences of self-induction; and in closed windings there is no tendency to produce internal circulating currents.

Involute Coils—Involute coils share the advantages of the dia-

FIG. 5—WINDING STRAP COILS

The former is in two parts. The ends of the coil are first roughly shaped to the former with a mallet and drift and then clamped into place. The two halves of the former are then separated by means of a lever which stretches the coil into its final shape with straight sides.

mond coils in that all are of a standard size and shape. They also require less space for end connection than any other form of coil. They are, however, difficult to insulate properly on account of the larger number of bends and are difficult to assemble in position in the armature. For this reason their use is restricted. The bar type of coil with involute end connectors is easy to insulate and assemble and can be readily repaired. Their principal use is for direct-current and industrial motors where end space must be reduced to a minimum.

Concentric Coils—Concentric coils can be used in any kind of slot. They can be hand-wound, machine-wound or "shoved through" (a combination of the other two methods), as best suited. The shape of coils is simple, hence they are easy to wind either on a mould or by hand. They can be adequately insulated, and can be securely braced with simple and reliable coil support. However, the coils belonging to the same group are of different size, and the coils in different groups, except on single-phase machines, are bent in at least two and often in three different shapes. This is a disadvantage from the electrical point of view, since there will always be a tendency toward unbalancing due to differences in self-induction, and toward the production of circulating currents in closed windings. And it is also a disadvantage from the mechanical point of view, since for one machine, a large number of different moulds will be required and coils cannot be interchanged. Hence, the number of spare parts necessary for repairs is greatly increased, and both the manufacturing and repairing of the winding will require more time and be more expensive.

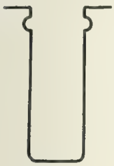


FIG. 6
OPEN SLOT

FIG. 7
PARTIALLY CLOSED SLOT

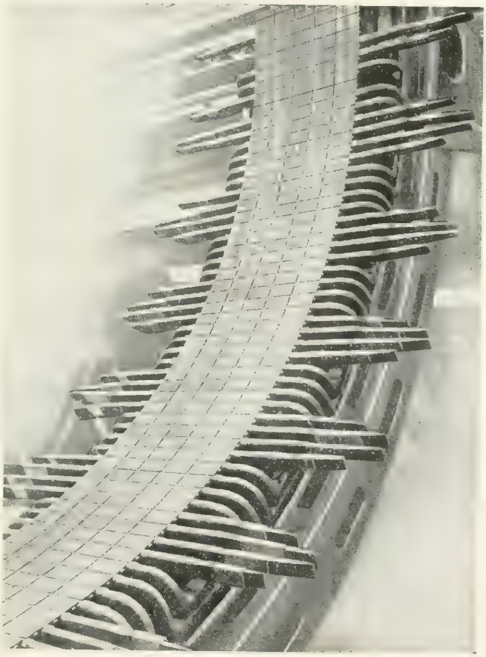


FIG. 8—CONCENTRIC COILS OF THE SHOVED-THROUGH TYPE

In position in the core, before making end connections.

THE SLOTS

The armatures on both direct-current and alternating-current generators and motors are built up of soft sheet steel punchings

provided with slots to hold the coils. These slots vary in dimensions, but are in general made either of the open form, as shown in Fig. 6, or of the partially closed form shown in Fig. 7. The partially closed slot gives a better distibution of the magnetic flux than the open slot because, with the exception of a narrow slit, the tips of the teeth close the space over the coils. The self-induction of a coil embedded in such a slot will be high; on the other hand, the machine is more adaptable to service where it may receive rough usage, heavy short-circuits, grounds, etc., for high self-induction will tend to reduce the current in the machine on such occasions. Moreover, the uniform flux distribution minimizes eddy current losses in the poles, making solid poles and small airgaps possible, thus reducing the material and labor costs.

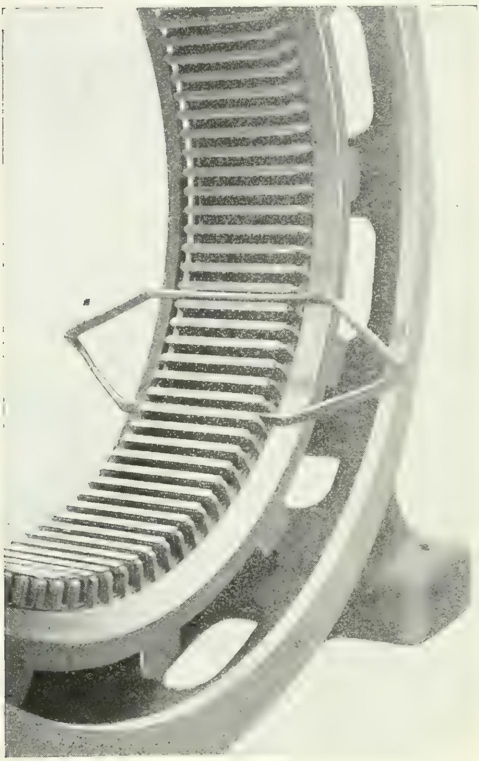


FIG. 9—DIAMOND COIL IN POSITION IN THE CORE

The principal disadvantage of the open slots is that they give a poor distribution of magnetic flux. The resulting eddy currents in the pole pieces tend to heat the poles and lower the efficiency of the machine. As shown before, however, the former or mould-wound coils, which can be used with open slots only, have many electrical and mechanical advantages over the other types, and the open slot has come to be very generally used, except for machines of special design.

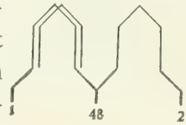


FIG. 10

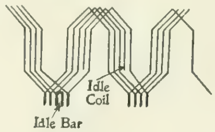


FIG. 11

THROW

The throw of a coil is defined as the position which the coil occupies in the armature as denoted by the number of the slot through which it passes from the front to the rear, and again from the rear to the front. For example, if a coil lies in slots *1* and *7*, the throw is known as *1* and *7*. In cases where the throw is equal to the total number of slots divided by the number of poles plus one, the throw is called the "pitch." For example, assuming 72 slots, 12 poles, and a coil lying in slots *1* and *7*; then $72 \div 12 = 6$, and $6 + 1$ = throw = pitch. Fig. 8 illustrates an armature core having concentric coils with a throw of *1* and *7*. Fig. 9 shows a diamond coil with the same throw.

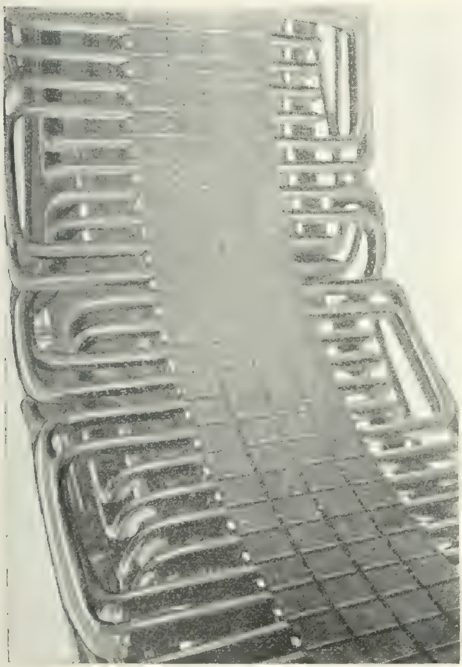


FIG. 12—CONCENTRIC WINDING

Showing twisted coil in the middle of illustration.

SPECIAL WINDINGS

With each general style of winding there are numerous variations, due to unusual characteristics of the machine, which may or may not affect the form of the coil and the method of winding. For example, in the case of a two-circuit progressive winding for a four-pole direct-current armature having 47 slots, 93 commutator bars and two coils per slot, since there are 94 coils and only 93 bars it is necessary in order to wind this combination that the ends of one coil be cut off, as illustrated in Fig. 10. The end of the coil is left in the slot to give the armature a uniform appearance.

Fig. 11 illustrates a two-circuit progressive winding for a four-pole direct-current armature having 41 slots, 82 commutator bars

and two coils per slot. Each commutator bar is connected to the ends of two coils, except one bar called an "idle" bar, which is in parallel with the bar adjacent to it.

Another instance of special winding is one which would be used on the three-phase, 14-pole, 84-slot armature. In this case each phase of the armature would occupy 28 slots and there would be two coils per pole. These coils would lie in slots *1-7* and *2-8*. Under these circumstances there would be $10\frac{1}{2}$ groups of coils, and in order to accommodate the half group, recourse is had to what is known as a "twisted" coil. This coil is formed by hand from two or more concentric shoved through type coils. In Figs. 12 and 13 are shown parts of an armature illustrating the method of winding such a case.

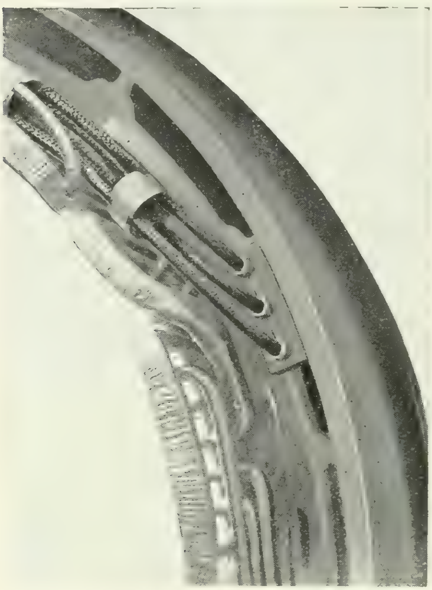


FIG. 13—END VIEW OF A TWISTED COIL

SMALL DIRECT-CURRENT MACHINES

THREADED-IN-FROM-THE-REEL TYPE

G. I. STADEKER

THE winding of the smallest types of direct-current armatures, with ratings not exceeding one and three-quarters horsepower, presents a problem different from that of any other type of machine. The inherent conditions impose the minimum possible working space, the use of miniature coils and the finest of wire. Combined with these is the necessity for noiseless operation, which is partially effected by using slot openings of minimum width. Under these conditions the threaded-in type of winding is practically the only type which can be used. In some cases mould wound coils

are used, but owing to the danger of injury to the coils in handling, the "threaded-in-from-the-reel" winding is more commonly used.

PREPARATION OF THE CORE

Skew-slotted cores have proven so effective in attaining noiseless operation that this design is quite generally followed for small capacity machines. In machines of this type the slot is skewed the width of one tooth, so that the conductors do not enter the magnetic field so abruptly as with the straight slotted cores. After the shaft has been turned to the required size and shape, the first operation is to assemble the core, which is made up of laminated punchings, such as that shown in Fig 14. A fibre sleeve about one inch long is slipped over the shaft and fastened in place by a cotter pin. This serves first as a stop for the laminations when they are slipped on the shaft, and later to protect the windings from contact with the shaft. For assembling the core, the inverted-U-shaped frame of the "building fixture," or jig, Fig. 15, is removed, and the shaft is set in a vertical position. The jig has a concave block, Fig. 16, fitted with a key, which runs diagonally across its concave surface and engages in one of the slots in each of the laminations as they are slipped over the top of the shaft. Uniform skewing is thus obtained.

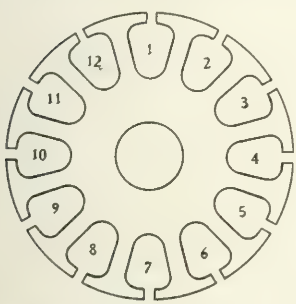


FIG. 14—ARMATURE PUNCHING

As the core is built up, the laminations are forced into close contact by striking them a couple of vigorous blows occasionally with a hollow tube or short piece of pipe slipped over the shaft. The first and last laminations are of fibre or fullerboard, punched to conform to the shape of the core, as a protection for the windings which cross the ends of the core. When enough laminations have been used to build up the core fully to the required height, a second fibre sleeve is slipped over the shaft, and the inverted-U-shaped frame replaced. The sleeve is pressed down on the laminations by means of the screw at the top of the jig until a cotter pin can be inserted to hold it in its proper position, thus tightly securing the core on the shaft. The openings of the slots are then filed smooth, and the core is ready for the windings.

WINDING THE COILS

As stated previously, the coils for direct-current machines up to one and three-quarters horse-power are wound from reels

directly upon the core of the armature. To facilitate this operation, the shaft, with the core mounted upon it, is inserted in a frame and mounted upon the spindle of a small winding lathe. Each slot is insulated with a cell of fish paper so shaped as to cover all the iron inside the slot, but leaving the opening of the slot unobstructed. (See Fig. 17.) Inside of this is placed another cell of waxed empire cloth, the edges of which project beyond the edge of the slot, and serve to guide and protect the wires during the winding operation. Each slot contains two distinct coils, insulated from each other by the empire cloth cells. These coils consist of a number of strands of wire wound simultaneously so that each slot holds four or six electrically distinct coils, all connected in series at the commutator.

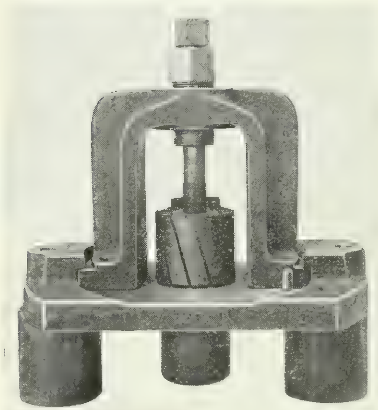


FIG. 15—JIG FOR ASSEMBLING ARMATURE CORES

The details of the method of winding are as follows:—Several reels of wire (determined by the number of strands specified per coil) are mounted so as to rotate freely. The ends of the strands from the several reels are then fastened to a part of the winding frame. Throughout the entire winding operation, these separate strands are treated as a single wire. The frame holding the core is revolved slowly while the wires are guided between the projecting edges of the cells. Starting at the commutator end of slot *1* on a 12 slot core (see Fig. 18), the wire passes over the back of the core and enters slot *6*, the slots being numbered consecutively. It is then guided forward, across the commutator end of the core and back into slot *1*. A counting device on the lathe spindle automatically records the number of turns, there being from 40 to 60 turns per coil on the standard machines. The coil is completed at the commutator end of slot 6, and a band of tape wrapped around the wires to distinguish the leads at the end of the coil from those at the beginning. The last layer of wire is tied with string to the pre-

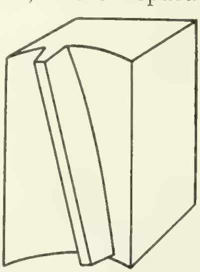


FIG. 16—BLOCK FOR UNIFORM SKEWING

vious layer, in order to hold it in position. A similar coil is then wound in slots *7* and *12*, beginning in slot *7*. When this is completed, the armature is rotated a part of a turn, so that the chords from slot *11* to slot *4*, and from slot *5* to slot *10*, will be parallel to the plane of rotation. The end connections of the coils already wound are protected from the coils next to be wound by semi-circular pieces of canvas, notched to fit closely against the shaft. Coils are then wound in slot *11* and *4*, and *5* and *10*, in a similar manner. The end connections of these coils are in turn protected by canvas and the last four slots are filled. This completes the winding of the coils in the lower half of the armature slots.

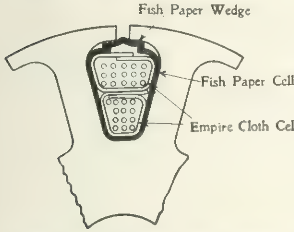


FIG. 17—SLOT INSULATION

Before proceeding, the armature is removed from the winding frame and each coil is tested for open-circuits, short-circuits and grounds. A circular piece of empire cloth, having a hole punched through its center to admit the shaft, is placed over each end of the armature to separate the lower layer of coils from the upper. The projecting edges of the cells enclosing the lower coils are cut off flush with the surface of the core, and folded down so as to cover the upper face of each lower coil. A drift is used to crease these cells in the inaccessible parts within the slot.

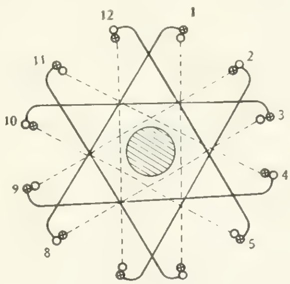


FIG. 18—WINDING DIAGRAM

A second empire cloth cell is then inserted in each of the slots to enclose the upper coils. These coils are wound exactly as the lower coils, except that the end connections of a given upper coil pass the shaft on the opposite side from that on which the lower coil from the same slot passes it. This is clearly shown in Fig. 18, in which the lower coils are indicated by dotted lines, and the upper ones by the solid lines. The order of filling the slots is shown in Table I, the brackets being used to enclose slot numbers the corresponding coils of which have parallel end connections.

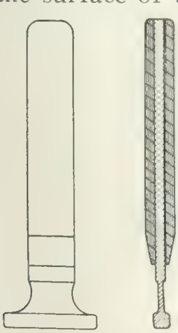


FIG. 19—ARM DRIFT

As each succeeding coil holds its predecessors in position at the end connections, no binding is necessary. The last two coils, however, have nothing whatever to hold their end connections in

TABLE I—WINDING TABLE

The coil numbers refer to the chronological order of winding. The brackets enclose coils having parallel end connections.

Lower Layer			Upper Layer		
Coil No.	Slot No.		Coil No.	Slot No.	
	Start	End		Start	End
{ 1	1	6	{ 7	2	7
{ 2	7	12	{ 8	8	1
{ 3	11	4	{ 9	12	5
{ 4	5	10	{ 10	6	11
{ 5	9	2	{ 11	10	3
{ 6	3	8	{ 12	4	9

place, and these are therefore tied together with string, which is wound around the shaft, thus firmly securing them from chafing.

The edges of the upper cells are trimmed and folded into the slots and a fibre strip is inserted in the slots between the windings

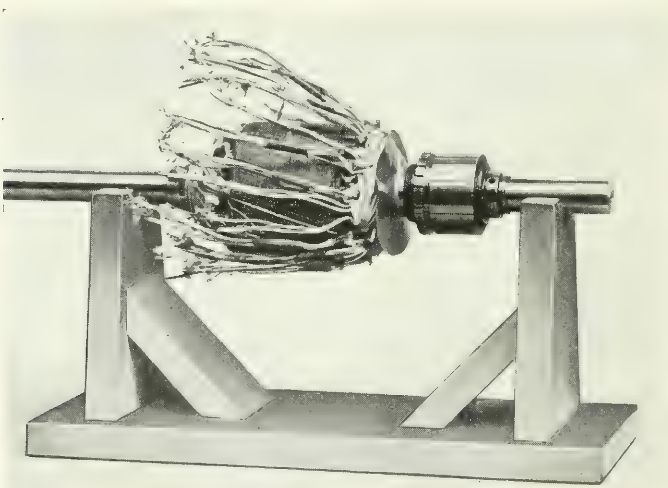


FIG. 20—ARMATURE BEFORE CONNECTING LEADS TO COMMUTATOR

and the teeth. An "arm" drift, of a shape as shown in Fig. 19, is slid into the slot between the teeth and this fibre strip and tapped lightly with a fibre mallet in order to force the coils into the recesses

of the slot. This fibre strip and the arm drift are then withdrawn, and in their place is inserted a fish-paper wedge.

In winding these armatures care should be taken that no two coils come in direct contact with each other at any point on the winding and that they do not touch the core. The wire should be held under even tension while being threaded into the slots, so that it will not kink or break. As it is very easy to scrape the insulation from the fine wire used in these machines, great care must be taken that the wire does not strike any sharp edges, and a continual lookout must be maintained for bare spots. The taping of the end of each coil, as a distinguishing mark from its beginning, must not be overlooked, for this becomes a matter of great importance when the connections are being made to the commutator. This band of tape should be applied before cutting the coil from the spool, thus avoiding any chance of confusing the wires.

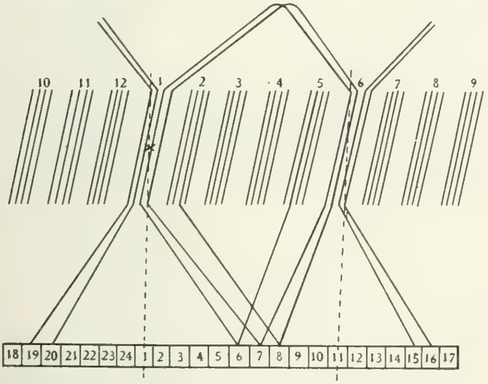


FIG. 21—DIAGRAM OF COMMUTATOR CONNECTIONS

If a lead from a lower coil in a certain slot is the beginning of a coil, the leads from the lower coils in the adjacent slots on each side of it must be the endings and vice versa. In other words, the slots must have alternately beginning and ending leads in each respective layer.

CONNECTING TO THE COMMUTATOR

The commutator is pressed onto the shaft by means of a hand press. Fig. 20 shows an armature as it appears just after the commutator has been pressed on. The hollow between the end connections of the armature and the commutator is filled with layers of friction tape up to the level of the bottom of the commutator bars, for the double purpose of protecting the end connections and forming a bed for the armature leads.

A working diagram of the armature connections, such as is used in actual shop work, is shown in Fig. 21. To connect a machine according to the diagram, the winder designates any slot as *1*. The commutator bar on a line with the central point of this slot is bar *1*. Slot *1* contains two sets of leads, one untaped and the other

taped, representing the beginning and the end of a coil respectively, as previously noted. The diagram calls for one of the coils in slot *1* to be connected to bar *6*. The lead should be laid across the slit provided at the rear of bar *6*, and the insulation scraped off with a knife, allowance being made for sufficient slack to place the leads as shown in Fig. 22. The gauge of the slits in the necks of the bars is made the same as that of the wire used in the coils, so that the wire makes a tight fit and is temporarily held in place by forcing it down into the slit. The other strands leading from this coil in slot *1* are placed in successive bars. The untaped leads in slot *2* are then inserted in the commutator, and so on around the

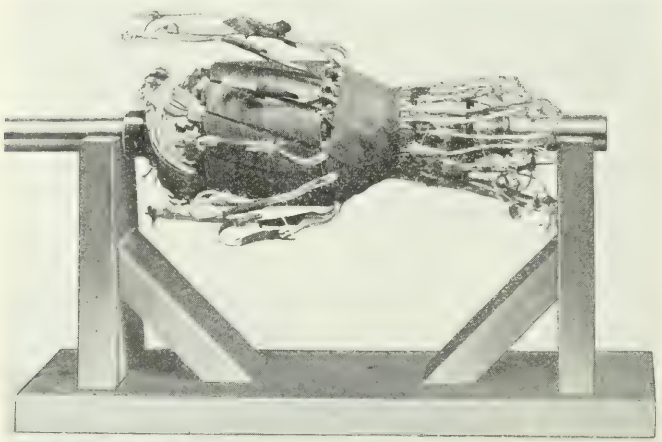


FIG. 22—LEADS FROM LOWER COILS CONNECTED TO THE COMMUTATOR

armature until all of the untaped strands have been fitted into their respective commutator bars.

The leads are forced into close contact with the friction cloth bed on which they are laid in passing from the slot to the commutator, by using a flat fibre drift and a mallet. The ends of the leads which project from the front of the commutator necks (See Fig. 22) are then cut off close to the shoulder on the commutator with a small chisel.

With the untaped leads thus placed, every bar should contain one lead. The taped leads are now bent back out of the way, and the leads already fastened to the commutator are covered with a layer of tape, to protect them from chafing against the taped ends, which must be laid across them to reach the proper commutator bars.

In connecting the taped leads to the commutator it is essential that the proper order be maintained. To assure this the coils are tested out with a test lamp, and the coil which is connected at one end to bar *6* is connected at the other end to bar *7*. Each coil is tested in a like manner, and connected as shown in the diagram.

Connecting to the commutator is one of the most important operations of armature winding. It is easy to confuse two wires where there are several exactly similar, and great care should be taken to make the correct connections. The armature leads are very often bared in places, and these should be taped wherever found. They are often abused by bending them back over the core and then laying the armature down carelessly, the sharp edges of the teeth thus scraping the insulation from the wire.

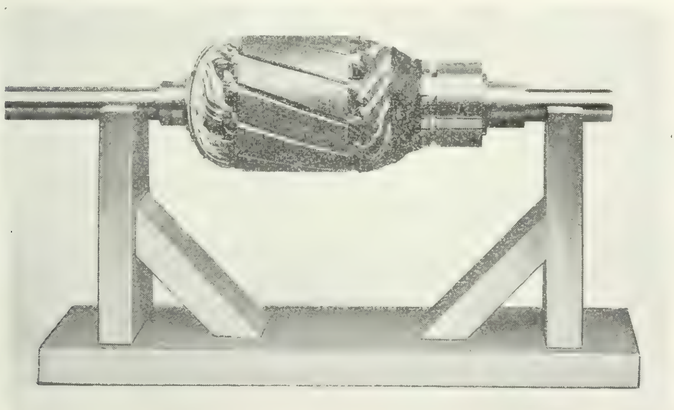


FIG. 23—COMPLETED ARMATURE

Before soldering the leads in the commutator bars, tests are made for open-circuits, short-circuits and grounds, the test voltage for all machines under 250 volts being 1 200 volts. If trouble is noted it should be corrected immediately. When everything up to this point has been completed satisfactorily, the armature is prepared for soldering by wrapping tape around the ends of the leads at the point where they enter the commutator. The commutator connections are then soldered, care being taken that no solder gets on the leads in the rear of the bars. The protecting tape over the ends of the strands is removed after the soldering is completed, as it is generally charred, and another layer of tape reaching all the way up to the core and entirely protecting the armature leads is applied in its stead. This forms a bed for a wrapping of twine, which gener-

ally extends about an inch back from the commutator, and firmly holds the leads in their proper position. The armature is then impregnated* and, after drying in an oven for 12 hours, the commutator is turned and balanced.

BALANCING

To test for balance, the armature is mounted on two exactly horizontal knife-edges. If it shows a tendency to rotate, it is out

FIG. 24—TOOLS USED IN WINDING SMALL MACHINES

The following tools and materials are required in winding small direct-current machines:

Tools	Materials
Spindle and winding frame	Punchings
Building fixture	Fibre sleeves
1 in. pipe—8 in. long	Wire for coils
8 in. triangular file	Winding cells
6 in. fine bastard file	Retaining wedges
8 in. scissors	Canvas
3 in. knife	Treated cloth
Steel and fibre drifts	Wax
Rawhide or wooden mallet	Impregnating varnish
Small steel hammer	
Small chisel 1-4 in. wide	
Soldering utensils	

of balance. Weights are applied wherever needed to correct any unbalancing.

Before being mounted in its frame, the assembled armature and commutator are given a final test for open-circuits, short-circuits and grounds.

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*"See article on "Impregnation of Coils with Solid Compounds" by Mr. J. R. Sanborn in the JOURNAL for March, 1910, p. 195.

A NEW FORM OF TUNGSTEN LAMP*

CHAS. F. SCOTT

THE tungsten lamp has very quickly established its claim as to high efficiency, excellent quality of light, and general acceptability. On the other hand, a feature of the lamp which is firmly fixed in the minds of all who have had to do with it is its fragility. Its liability to accidental breakage in handling and in service is its great handicap. Whenever, therefore, an improvement is made in the materials or construction of the lamp which will materially reduce its fragility, an important commercial advance has been made.

The "wire type" is the name of a new form of tungsten lamp developed by the engineers of the Westinghouse Lamp Company which possesses several characteristics which mark an advance in the metal filament lamp, and which commend themselves to those who use these lamps. The new type of lamp has a mechanical construction which is fundamentally much stronger than that of the ordinary lamp employing filaments of tungsten, whether of the so-called tungsten, wolfram, kolloid, or Mazda variety, while its other qualities insure an excellent performance.

FRAGILITY

Why is the ordinary tungsten filament lamp so fragile? It is so on account of both the material of which the filament is made and the way in which it is held. The tungsten filament is mechanically quite similar to glass. A slender rod or thread of glass has a great tensile strength and it can be bent; the smaller the diameter the more can it be bent without breaking. But it is fragile and a slight blow shatters it. When it is warm it becomes quite soft. This description applies equally to the tungsten filament. Now either a glass or a tungsten rod or filament if rigidly held at one point is much more apt to break than if loosely supported. If one wished to ship a glass rod, he would either bind it to a stick, and thus support it throughout its entire length, or he would pack it in soft material. The worst way to hold it would be to fasten it rigidly to heavy supports at its ends. And yet the fragile tungsten filament is held rigidly at its ends. Furthermore, in the ordinary

*From a paper read at the 23rd annual convention of the National Electric Light Association at St. Louis, May 24, 1910.

lamp the total filament consists of four or five hair-pin shaped parts, each rigidly fastened to stiff wires at its ends, making a total of eight or ten points of rigid support.

The support is made absolutely rigid usually by electrically welding or fusing the supporting wire around the tiny filament. Mechanically this is the ideal way not to hold the fragile tungsten thread. And the logical result follows, one of the best known features of the lamp is its fragility, and the mechanical break almost

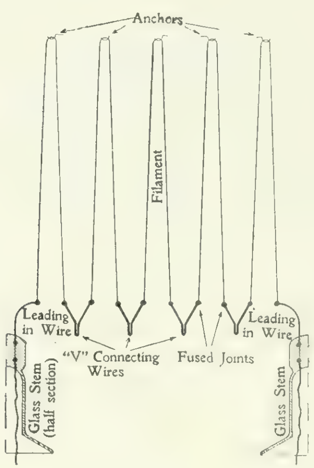

FIG. I—DEVELOPED SECTION OF ORDINARY TUNGSTEN LAMP

Each filament is fused at each end to relatively heavy leading-in or "V" connecting wires.

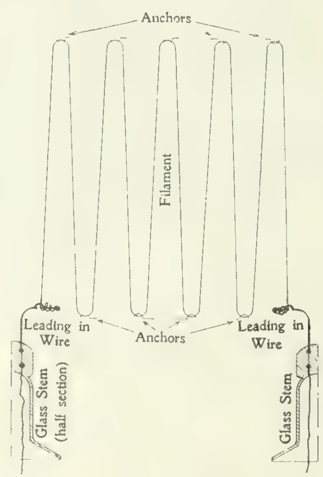

FIG. 2—DEVELOPED SECTION OF WIRE TYPE TUNGSTEN LAMP

A continuous filament is connected at each end to a leading-in wire by a spiral winding and a fused joint at its extreme end.

invariably occurs near the fused support. Now, the reason for this unfortunate construction is that tungsten filaments are ordinarily made in short lengths in hair-pin shape. It has not been practicable by usual methods to make and mount single filaments having a length of the 30 inches, more or less, which is necessary for a 110 volt lamp. Consequently, it has been common practice to connect in series a number of individual short filaments by fusing their ends to stiff supporting wires. Hence, the mechanical monstrosity of rigidly supporting a delicate and fragile filament results from the necessity of using many individual filaments, adapted in length to the size of the lamp bulb.

The ideal way to overcome these difficulties is to employ a single filament, and to mount it without fastening it rigidly to its supports. This requires three things: first, a single or continuous filament; second, it must be wound back and forth and loosely supported at numerous points, giving a final form appropriate to the ordinary lamp bulb; and third, the ends of the filament must make a suitable electrical contact with the leading-in wires, without the fatal rigidity. These elements are realized in the new form of lamp.

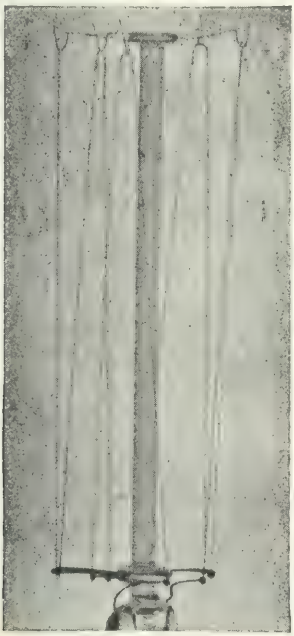

FIG. 3—METHOD OF MOUNTING FILAMENTS IN ORDINARY TYPE OF TUNGSTEN LAMP

The ends of the filaments pass through metal balls fused at the ends of the supporting wires.

The thing which makes the new lamp possible is the development of a new method of manufacturing the filament by which it is produced in long lengths. It is then ready to be wound, like wire from a coil. A few turns near each end of the filament are wound in the form of a spiral spring around the respective leading-in wires, and to further insure contact the ends are fused. The fused and rigid connection between the leading-in wire and the end of the filament is thus protected from the straight part of the filament by the several turns of the filament around the leading-in wire, these turns acting as a sort of spring, so that a slight bending of the filament resulting from a blow or vibration does not act directly upon the fused joint, as it would if a straight part of the filament came directly from the fused joint, as in the ordinary construction. Furthermore, any carelessness in the act of fusing which may damage or weaken the filament is of minor consequence in the wire type lamp; whereas it may seriously lessen the strength of the filament in the common form of lamps. Hence, the three elements, a single long filament, intermediate supports which hold the filament loosely and a terminal which is mechanically and electrically satisfactory, are all secured in the new wire type lamp.

QUALITY AND UNIFORMITY

Not only does the single long filament permit improved mechanical construction of the lamp, but it insures a quality and uniformity in the filament which are essential to a good lamp. It is well known that when either carbon or tungsten lamps are to be operated in series, special precautions are necessary in order to secure lamps that are similar. If they are unlike, then the lamp which has a normal current less than the others burns too brightly, as all of the lamps are forced to receive the same current, and hence its life is shortened. In the ordinary type of tungsten lamp in which several independent filaments are connected in series, the condition is very similar to the operation of independent lamps in series. If, therefore, the filaments are not identical, the smaller or weaker filament will have too great a current forced through it, thereby shortening its life. The condition is more unfortunate than when independent lamps are burned in series, for the reason, that when there are independent lamps, the burning out of one does not affect the others. On the other hand, when one filament in a lamp burns out, the other filaments, although they may be in first-class condition are useless. These conditions will be more clearly understood if definite examples are cited.

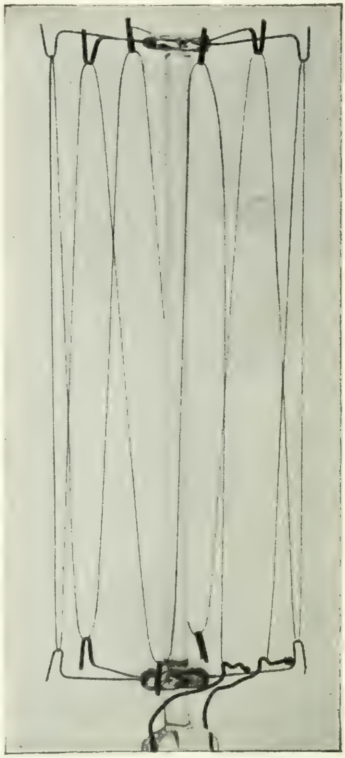

FIG. 4—VIEW OF WIRE TYPE TUNGSTEN LAMP, SHOWING CONTINUOUS FILAMENT

The ends are wound around the leading-in wires and fused at the extreme ends.

If five carbon lamps are connected in series on a 500 volt circuit, four of which are alike, and have a normal current of 0.65 of an ampere, and the fifth lamp has a normal current of 0.64 ampere, or 1.5 percent less, then when the lamps are operated in series, the four lamps will be burning under practically normal conditions, while the fifth lamp will have current approximately 1.5 percent

above normal. The result is that the life of this lamp is reduced below that of the others by about 25 percent. If, instead of carbon lamps, tungsten lamps be used, four of which are alike, and the other has a normal current 1.5 percent below the others, then the reduction in life when all are operated in series will be approximately 33 percent. The fact that tungsten has a positive instead of a negative temperature coefficient causes the watts consumed in a tungsten lamp to increase more with a given increase in current than do the watts in a carbon lamp. Therefore, the tungsten lamp, which is less sensitive than the carbon lamp to change in voltage when lamps are connected in parallel, is on the other hand more sensitive than the carbon lamp to a change in current when the lamps are operated in series. If, instead of operating five separate lamps, we consider the performance of five filaments connected in series in the same lamp, one of which has a normal current of 1.5 percent less than that of the other four, we will have a condition analogous to that of the five independent lamps in series. It follows, therefore, that the weaker filament will have a life which is normally 33 percent less than the other filaments; consequently, the life of the whole lamp is far less than it would be if all five filaments were alike, either all similar to the larger filaments or all similar to the small filament.

The practical bearing of the importance of small differences in filaments will be appreciated when the conditions in the manufacture of individual filaments are mentioned. Variations due to the use of different dies, or the same die at different periods in its service, and variations in the different stages of the process of treating or forming the filament are liable to cause minor differences. In general, therefore, a lamp in which the filaments are individually and independently produced is liable to variations and differences which can be avoided only by very careful and accurate selection.

The accurate sorting and classification of tungsten filaments which are to be used in the same lamp is ordinarily accomplished by electrical measurement. This is not only a convenient method, but it is essential on account of the nature and size of the filament. Tungsten filaments usually have a slightly roughened surface as viewed under the microscope so that it is impracticable to secure a definite, exact measurement of the effective diameter. Even were the filament perfectly cylindrical, the mechanical measurement would involve infinitesimal quantities. For example, the filament of the

ordinary 25 watt lamp is approximately 0.001 inch in diameter. A difference in diameter between two otherwise similar filaments of as much as one percent would be entirely inadmissible. As one percent is 0.00001 of an inch, it is obviously fortunate that no such measurements have to be made, but that electricity itself affords a ready and convenient method of determining the uniformity by electrical measurement.

It is evident that a process in which a yard or more of filament is made in one piece is not liable to the differences which are possible and probable when a lamp contains several filaments which have been made at different times and under the necessarily dif-

TABLE I.

Tests showing distance in inches through which the weight was dropped when filaments broke, in wire type and fused lamps; also ratio of average distance required for the two types.

Lamps	60 Watts		40 Watts		25 Watts	
Vertically Pendant	Wire	Fused	Wire	Fused	Wire	Fused
Five Weakest.....	33.6 in	3.6 in	32 in	6 in	14.8 in	2.0 in
Five Strongest....	40.0 "	14.0 "	40 "	12.4 "	17.6 "	5.6 "
Average	36.8 "	8.8 "	36 "	9.2 "	16.2 "	3.8 "
Ratio.............	4.21	1.0	3.9	1.0	4.3	1.0
Horizontal						
Five Lamps........			40 in	6.4 in	36.8 in	6.4 in
Ratio.............			6.2	1.0	5.7	1.0

ferent conditions which are incident to commercial manufacture. Owing to the uniformity of treatment which the single long filament receives and the resulting uniformity in diameter and in character, the selection of filaments by resistance measurement which is absolutely essential in the ordinary manufacture of lamps with separate filaments is practically eliminated.

MECHANICAL TESTS

The mechanical excellence of the lamp is attested by the results of some simple experiments in which lamps of the wire type have been put under identical tests with lamps of the ordinary type having several filaments fused to the supporting wires.

Lamps of the fused type from different makers showed a substantial equality among themselves under similar tests. In one test, lamps were mounted in wall sockets which were screwed to an ordi-

nary poplar board one-half inch thick and six inches wide, which was held on supports about four feet apart. Sockets were attached to this board as shown in Fig. 5, and were supplied with lamps of the two types respectively. In the first test, the lamps were in the ordinary pendant position under the middle of the board. An iron weight, sliding freely on a guiding rod which was fastened to the

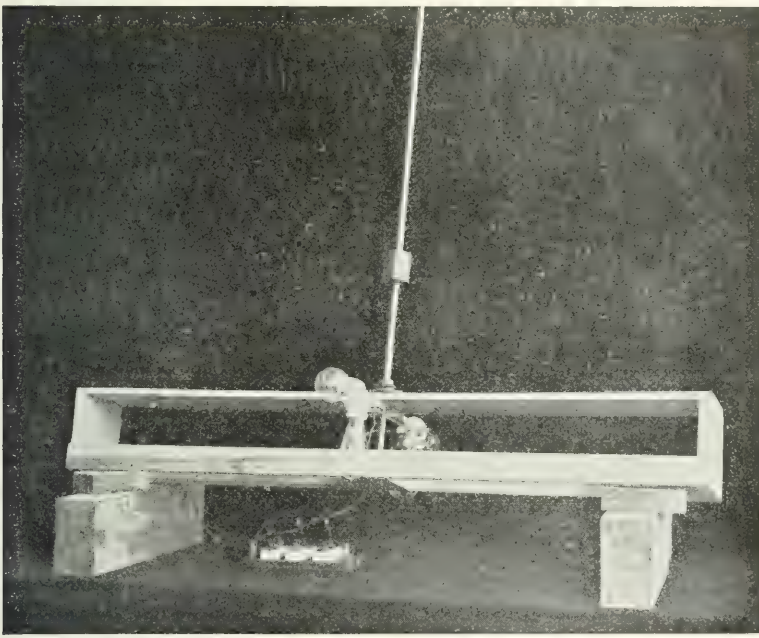

FIG. 5—APPARATUS USED IN TESTING THE MECHANICAL STRENGTH OF TUNGSTEN LAMP FILAMENTS, WHEN SUBJECTED TO A SHOCK BY THE DROPPING OF A WEIGHT

The apparatus is shown tipped back for convenience in photographing. Lamps of two kinds were placed in the pendant positions in the first test and in the horizontal positions in the second test. The weight was allowed to drop freely over the vertical rod and strike the light upper board to which the lamps were rigidly attached. It was dropped from successive heights until the lamps broke.

board on which the lamps were mounted, was then dropped upon the board, thus representing, in a general way, the condition in which a lamp is attached to a ceiling where it is subjected to jar from overhead. Each time the weight of 1.75 pounds was dropped, the distance was increased by two inches. Ten tests each were made on 60-watt, 40-watt and 25-watt sizes. In each test two lamps

were used, one of each type in the two similar sockets, each type of lamp being placed alternately in each socket to insure identical conditions of test. There was no current through the lamps when the weight was dropped, but current could be applied to determine whether the filament was broken. The distance through which the weight dropped when each lamp broke was noted and the average was taken of the five lesser values and also of the five larger values. These are recorded in the first part of Table I. The apparatus did not admit of dropping the weight from a height of more than 40 inches, and in cases where a drop of this distance was not sufficient to break the lamp, the value of 40 inches was used in calculating the averages, although this gives a less value than the true one to which the lamp is entitled. The results show that the breakage of the wire type requires that the weight be dropped from about four or more times the height that causes destruction of the fused type of lamp.

A second and similar dropping test was made with the lamps in a horizontal position instead of a vertical position. A weight of

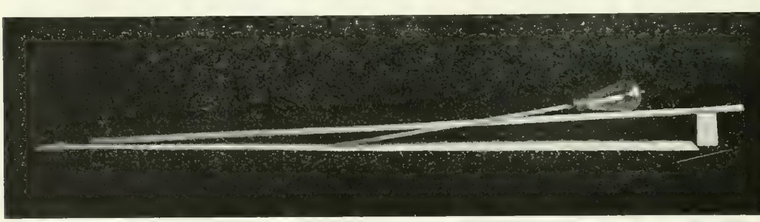

FIG. 6—APPARATUS USED IN TESTING MECHANICAL STRENGTH OF LAMP FILAMENTS WHEN ROLLED OFF A BOARD ONTO A TABLE TOP

1.1 pounds was used. The average results of tests on five lamps of each type of the 40-watt and 25-watt sizes are shown in the lower portion of the table. From this it appears that the average wire type lamp can withstand the dropping of the weight from about six times the height that is fatal to the fused type.

An additional mechanical test of another kind was made by rolling the lamps off a board onto the top of a table. The height of the fall was gradually increased. In order that the lamp might strike on its side, a light wooden guide rod was attached to a thin copper socket so that the lamp would maintain its axis approximately horizontal at all times. The height from which the lamp was rolled was increased between tests. The apparatus is illustrated in Fig. 6. The average height from which the lamps were

dropped when the filament broke shows that the wire type can withstand approximately twice the fall that the fused type can withstand. The mechanical tests in the aggregate show that the wire-wound type of lamp is much less liable to injury than the fused type lamp when subjected to blows which are of a kind similar to those which may be expected in service.

The wire type tungsten filament is made in long lengths, the present equipment making several miles a day. The wire type of lamp has been under experimental development for a year and a half, and some of the lamps were in service early in January, 1909.

Both the simple underlying theoretical considerations and the results of the tests which have just been described indicate that this lamp possesses elements of superiority both with respect to inherent quality and mechanical strength. The inherent uniformity in the new continuous filament removes the frequent causes of vexatious early failure in the ordinary type of lamp as it eliminates the possibility of unlike filaments, the disadvantages of which have been amply illustrated. The continuous filament does away with the several sources of weakness at the fused joints as well as having a physical strength which will go far to obviate early breakage from accidental causes. As a result of these new features the tungsten filament lamp will presumably meet with still greater favor in popular service.

MAGNET SWITCH CONTROL FOR DRIVING-WHEEL AND CAR-WHEEL LATHES

J. H. KLINCK

LOCOMOTIVE driving wheels and car wheels tend to wear unevenly and, as the wheels will not remain on the tracks unless both treads and flanges are kept approximately correct, it occasionally becomes necessary to true them up in a lathe. The turning of these wheels is frequently rendered difficult on account of the so-called "hard spots" on the surface of the wheels, caused by skidding on the rails. When the brakes are set too tight, they prevent the wheels from turning and cause them to slide along the rails. The friction between the wheels and rails develops intense heat and the metal at the points of contact becomes so much harder than that in the rest of the tire that it cannot be removed in the lathe at the same rate as the unaffected metal. A number of such hard spots may be distributed over a single wheel. In trueing such wheels it has been customary either to chip out the hard spots by hand or, when there are too many of them, to turn the whole tire at the rate required by the hard spots. Either of these methods is a very slow process but, previous to the use of motor-driven tools, they were the only practical methods of meeting the situation. With a tool operated by an adjustable speed motor, however, it is possible to adjust the cutting speed as required, slowing down while going through hard spots and returning to normal speed as soon as they have been passed.

The performance of motor-driven machine tools equipped with manually operated controllers is, to a large extent, dependent on the personal characteristics of the individual operator. To secure uniform operation it is necessary that certain restrictions be placed on the handling of the controller, for many workmen have an idea that the output is increased by the rapidity with which the motor is started and stopped. This is true to some extent, but when the motor is accelerated too rapidly, the value of the time saved is overbalanced by the disturbance on the distributing system, and the damage to the motor, gearing, etc. With automatic magnet switch control the motor can be accelerated at a predetermined rate without attention from the operator. Small auxiliary control switches can be installed on the

lathe wherever desired and the motor controlled from the point most convenient for the operator.

A Sellers car wheel lathe which is in operation in the repair shops of the Chicago Railway Company is equipped with a controller designed to meet the needs of this class of service.

This lathe, as shown in Fig. 1, is driven by a 35 hp, 515-1030 r. p. m. direct-current shunt motor, geared to the driving shaft. In this illustration the wheels have been turned and the air hoist is shown ready to remove the wheels from the lathe. To do this the tail stock is moved by means of the motor, just showing above the floor line on the extreme right; the wheels then fall from the lathe centers into the frames of the hoist; the latter is moved slightly to the right on the overhead track, and the wheels are lowered to the floor level and

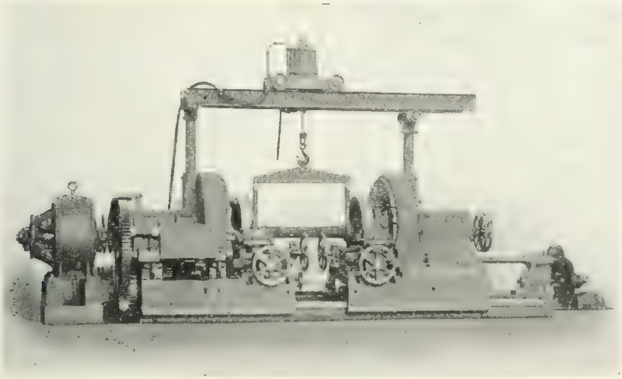

FIG. 1—SELLERS CAR WHEEL LATHE, DRIVEN BY A 35 HORSE-POWER DIRECT-CURRENT MOTOR

rolled away. The operation is reversed when placing a pair of wheels in the lathe.

The magnet switch motor control panel used with this lathe is shown in Fig. 2, and the electrical connections of the controlling apparatus and motor are shown in the diagram, Fig. 3.

On operating the master controller full voltage is first impressed on the field circuit and then on the control switches, and these switches automatically start the motor and bring it up to speed. First the motor is connected to the line with all the starting resistance in series by magnet switch *I*. Magnet switches *II*, *III*, and *IV*, which operate by the drop in resistance method, then

short-circuit the resistance in sections. The master controller can be set at any desired position of field control without damage to the motor, as the field resistance is short-circuited by auxiliary contacts *3* and *4* until the last section of starting resistance is cut out. The motor will thus start with full field strength under all conditions. The opening of contacts *3* and *4*, cuts into the field circuit such part of resistance R_{13}—R_{23} as is not short-circuited by the master controller. Resistances R_4 to R_9 and R_9 to R_{13} are short-circuited by the relay switches *VI* and *VII*, which are operated by the closing of contacts *1* and *2*. The rate of operation of these two switches is controlled by the adjustable dashpots shown at their base in Fig. 2. When relay switches *VI* and *VII* are open, the speed of the motor is regulated solely by the position of the master controller.

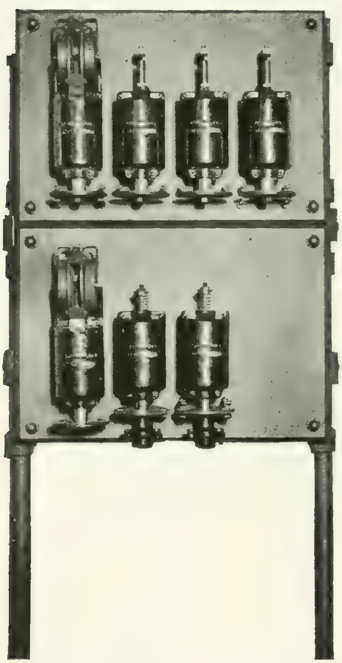

FIG. 2—MAGNET SWITCH MOTOR CONTROL PANEL

The auxiliary switch use in starting and stopping is connected in series with the master-controller contacts of the pilot circuit. If either the master controller or the auxiliary switch is in the off position, the pilot circuit is open and the motor disconnected from the line. Thus the motor may be started and stopped from either the master controller, the auxiliary switch or the main line switch, provided the other two are in the running position. In operating the auxiliary switch it should be remembered that the field of the motor is excited at its maximum value whenever the master controller is in the running position, but the motor not running. Hence the auxiliary switch should never be used to shut down for any length of time.

The auxiliary switch used for slowing down is connected in the pilot circuit between the windings of magnet switches *III* and *IV*, between contacts *2* and *5*. As long as this auxiliary switch is open, magnet switch *IV* cannot remain closed, and the

resistance R_3 to R_4 is inserted in the armature circuit, while at the same time all the field resistance is short-circuited, giving a speed below the minimum obtained by field adjustment. The exact speed obtained will, therefore, depend upon the load on the motor; the less the load the higher the speed. In this particular equipment, when the motor is developing full-load torque the speed is reduced to approximately 200 revolutions per minute by the opening of the "slow down" switch.

Ordinary snap, pendant or single-pole knife switches may be

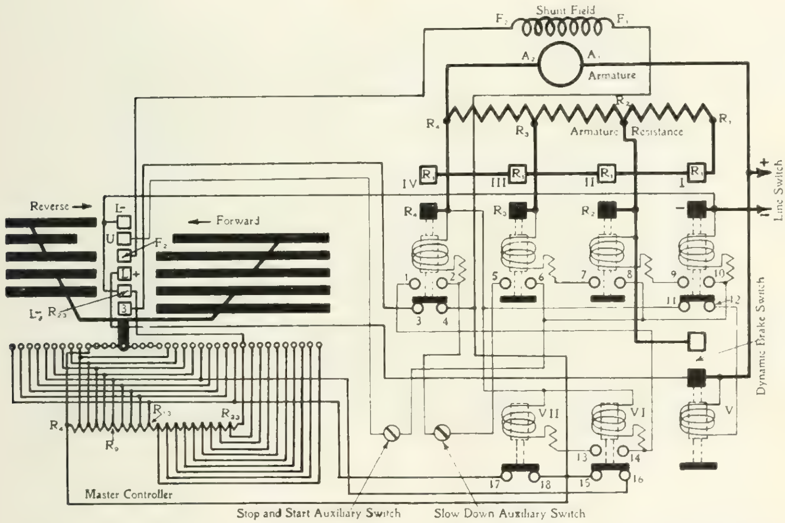

FIG. 3—DIAGRAM OF CONNECTIONS OF CONTROLLING APPARATUS AND MOTOR

Rear view of panel. All moving contacts are shown solid, the main stationary contacts as open squares and auxiliary contacts as open circles. Main wiring is shown by heavy lines, field circuits by medium, and control circuits by light lines.

used for this purpose, and they may be located as desired, as their sole function is to make and break the current in the pilot circuit, which never exceeds one-half ampere. In this installation snap switches are mounted on the lathe near the cutting tools. As the cutting tool comes near a hard spot the slow down switch is opened, and left open until the need for the slow speed has passed, when the switch is again closed and the normal speed resumed. If desired this switch may be connected to short-circuit the field resistance without cutting in armature resist-

ance, or to cut in any portion of the armature resistance, its effect depending on which control circuit it interrupts. Any number of these auxiliary switches may be used, all of each kind being connected in series with the master controller. All the switches must then be closed to operate the motor.

This installation is also furnished with dynamic brake connections for quick stopping. When magnet switch *I* opens, contacts *11* and *12* are bridged and the terminals of the pilot circuit of dynamic brake switch *V* are connected across the motor brushes. This energizes the winding and causes the switch to close and connect the resistance R_2 to R_4 in series with the armature, practically short-circuiting it. As the motor stops the potential across the brushes falls, and the switch coil *V* loses its excitation. Consequently this switch opens, a blow-out coil extinguishing any arc. If an attempt is made to start the motor from either the master controller or the auxiliary switch while the dynamic brake is in operation, the bridge between contacts *11* and *12* is broken by the upward movement of the plunger of magnet switch *I* and the dynamic brake switch opens, thus preventing any possibility of connecting the armature to the line with insufficient starting resistance in circuit.

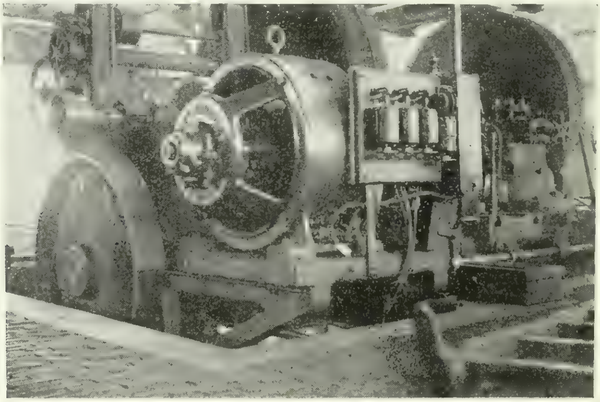

FIG. 4—FIFTY HORSE-POWER MOTOR AND CONTROL EQUIPMENT FOR DRIVING-WHEEL LATHE

A driving wheel lathe in the shops of the Western Railway of Alabama, at Montgomery, Ala., equipped with a similar controller is shown in Fig. 4. This equipment is without the dynamic brake and auxiliary switch for slowing down, but a pen-

dant switch hanging on the back of the lathe is used as an auxiliary switch for starting and stopping. Fig. 5 shows the master controller for the main motor and in the right foreground the controller for the tail stock motor. The master controller can easily be reached from the operator's position, and the controller for the tail stock motor is so located that the operator can see when the lathe centers and axle centers are in contact. This lathe is driven by a 50 hp., direct-current shunt motor, 500-1000 r.p.m., by the use of a Morse chain.

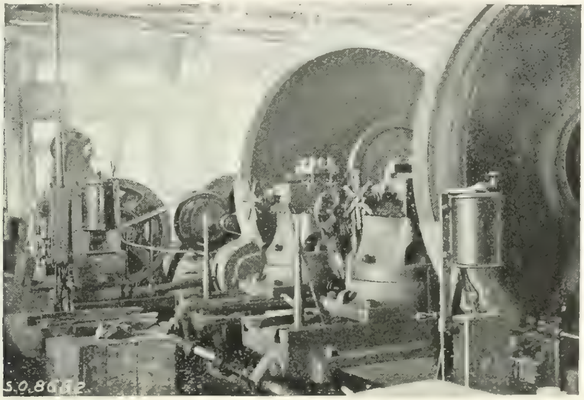

FIG. 5—OPERATOR'S POSITION AND CONTROLLERS OF DRIVING-WHEEL LATHE

By reason of its flexibility and automatic operation, magnet switch control of motors is ideal for this class of service, as maximum output is secured under best operating conditions at all times. The apparatus is protected from improper starting conditions, and the operator, freed from the responsibility of operating the motor, can devote his undivided attention to the work in progress.

THREE-PHASE RAILWAYS IN EUROPE (Concluded)

RUDOLFH E. HELLMUND

SAVONA-SAN GIUSEPPE ROAD

This road is, in its general characteristics, very similar to the Giovi road. In this case again, electrification is introduced to take care of the severe grade conditions on the southern side of the Apennines. The power station is under construction at Vado near Savona. It is situated near the seashore at one end of the line. It will contain three steam turbine units of the type used on the Giovi road. The locomotives will also be duplicates of the Giovi type.

THE SIMPLON TUNNEL ELECTRIFICATION

The electrically equipped Simplon tunnel has been in operation for about two years. The reason for electrifying this road was chiefly because of the difficulties which were anticipated with steam operation in a tunnel of such length, viz., about 12.5 miles. Up to the present time only the tunnel section between the terminal stations on either side of the mountain has been electrified. However, the results obtained with electric operation compare so favorably with those of the steam-operated section of the road that an extension of the electrification towards the South is contemplated. The power is supplied by two hydro-electric power stations, one being situated near each end of the tunnel. The operating expenses are only about 55 percent of the expenses for an equal length of road operated by steam.

These stations, like the power house of the Giovi road, are equipped with water rheostats controlled by the governors of the prime movers, for taking care of any excess of current regenerated by the locomotives when operating on down grades. The resistances consist of a water basin into which three electrodes are immersed when a load is to be dissipated by them. Except in this detail, the Simplon stations differ but little from other three-phase stations.

The operating conditions on this road are, in a way, very severe for electrical apparatus, on account of the climatic conditions. At the ends of the tunnel the locomotives are frequently exposed to snow storms and much snow is apt to accumulate on all exposed parts. A locomotive, after becoming very cold in the outer air, enters the tunnel in which the temperature is always high on account of hot springs located therein. The snow is quickly melted, all parts

covered thereby becoming extremely wet. The other parts, even the protected portions of the motors, also become wet by the time a locomotive reaches the other end of the tunnel because all the cold parts serve to condense the moisture held in suspension in the hot, damp air of the tunnel, on all parts of the locomotive. The fact that the double trolley does not give the least trouble with a potential of 3 000 volts, seems to indicate that much higher potentials can safely be used under less severe conditions.

The load conditions of this road are about as follows:—The average weight of a train is about 300 tons, trailing load, and the

FIG. 10—SIMPLON TUNNEL LOCOMOTIVE

Showing arrangement of main and auxiliary bows on the current collector.

maximum slightly above 500 tons, trailing load. But one locomotive is used per train, there being normally but one start for each trip of 13.5 miles; quite frequently, however, they have to stop and start a second or third time within the tunnel. Each locomotive makes between 18 and 25 trips of 13.5 miles per day. The maximum grade of the road is only 0.7 percent.

Three types of locomotive have been operated on the road. Before the Simplon locomotives were completed some of the Valtellina locomotives were used and gave entire satisfaction. Then two locomotives, built by the Brown-Boveri company, were placed in operation. These locomotives have two 3 000 volt motors with wound

secondaries, each motor being wound for two speeds. One of these locomotives is shown in Fig. 10. Of more interest than these older locomotives are the two equipments furnished later by the Brown-Boveri Company. The motors of the latter are of the squirrel cage type and are wound for four economical operating speeds. In view of the fact that squirrel cage motors are considered to be inherently poor for severe starting conditions such as prevail in railway work, their successful application in this case is quite noteworthy. Although the starting conditions of the Simplon road are by no means as severe as are many others, it has been demonstarted that the squirrel cage motor is worth while to be considered for the railway work of the future.

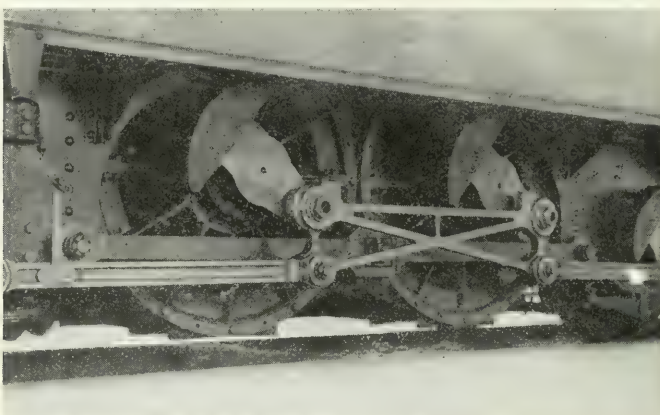

FIG. 11—SIMPLON TUNNEL LOCOMOTIVE
Showing details of mechanical construction of running gear and end brackets of the two motors.

While the steam locomotives on this road are given an inspection after each 50 000 miles of travel, the locomotives with the squirrel cage rotors ran 87 000 miles before the first inspection was made. The locomotives have been used to start as heavy as 1 000 ton trains on a slight curve and on a maximum grade of 0.4 percent, this being the severest load which could be obtained for testing purposes.

The interior of the locomotive gives one the impression of great simplicity. The auto-transformers and drum type switches for starting the motors are symmetrically arranged in the cab hoods at either end. The four pole changing switches are symmetrically arranged at the sides of the cab. Between these switches the revers-

ing drum is arranged on one side and a small motor-generator set for lighting purposes on the opposite side of the cab. All of the apparatus is enclosed in cabinets on account of the high potentials used. By opening the door of any cabinet the apparatus inside may be conveniently inspected. The entire middle space of the cab is free, except that the floor is about one foot higher in the middle above the motors than at the ends. None of the apparatus, except the levers and instruments, is normally visible. The writer did not have an opportunity to ride in these locomotives but watched them while they were started and could not hear the least vibration, although some might be expected on account of the large short-circuit

FIG. 12—DETAILS OF OVERHEAD CONSTRUCTION USED OUTSIDE OF TUNNEL ON THE SIMPLON ELECTRIFICATION

currents in the motors. The trains start rather slowly; this, however, seems to be on account of the limited capacity of the power stations, there being no other reason why the locomotives should not accellerate more rapidly.

Parallel Operation of Locomotives—Some difficulty might be expected when locomotives of different wheel diameters are operated in parallel. However, the conditions for the parallel operation of locomotives in the case of the Simplon tunnel are not very difficult. The maximum wear of the wheels is only about 1.375 inch or about 3 percent, and the squirrel cage motors are designed for six to eight percent full-load slip.

Motors—The motor weight is 13.5 tons. The rotors of the motors although they have to dissipate all starting losses have never yet been repaired. The motors and some features of the mechanical construction of the locomotives are shown in Fig. 11. As will be seen from this illustration, the end shields of the motors are open and thus the rotor windings are exposed to the open air. The end connections of the stator winding are, however, enclosed by protecting shields. The stator cores are of the open slot type and the coils are completely insulated before being placed into the slots. This feature is not in line with European practice in general, but it was probably adopted because the placing of two separate stator windings of the concentric type, which is usually employed on the continent, leads to various difficulties. When considered in relation to their output, the dimensions of the motors are comparatively large. This is partly due to the small ventilation of the stator, partly to the fact that certain allowances had to be made for the startling losses which have to be dissipated in the motor; also, the use of two stator windings tends to increase the motor dimensions. This, however, is fully made up for in various respects. The squirrel cage feature of the motors eliminates the starting resistances otherwise necessary and reduces the weight of the starting apparatus to that of the small starting auto-transformers, while the use of two stator windings gives the advantage of four economical operating speeds. The motors seem to have a starting torque much in excess of what is usually required since it has been found advisable to introduce an extra resistance into the lowest voltage lead of the transformer, which gives in itself only one-third of full-load potential. The practice of using the two stator windings simultaneously for starting, as mentioned by Messrs. Thoman and Schnetzler,* presumable has been abandoned on account of the large internal higher harmonic currents.

Control System—One's impression regarding the control system is that it represents a happy medium between pneumatic and hand-operated systems. It is, of course, next to impossible to arrange everything for hand control so that all operations may be controlled from one place. Therefore, a limited number of switches, e. g., the pole changing switches and the reversing drum, are operated by compressed air. The tap contacts of the auto-transformers, however, which, if pneumatically operated, would require a multitude

*See *Zeitschrift des Vereines deutscher Ingenieure* for 1907, p. 607.

of valves and pipes, are controlled by hand-operated drums. There are altogether four of these drums, two for each motor, and all of them are interconnected by chains.

Overhead Construction—The important features of the overhead construction of the Simplon electrification are shown in Figs. 12 and 13. Although the entire construction is rather light, it seems to stand up satisfactorily and has given no trouble during a period of continuous operation of several years, with a maximum locomotive speed of 45 miles per hour. The switches are passed at maximum speed with the collectors up instead of lowering them, as has been found necessary in some cases.

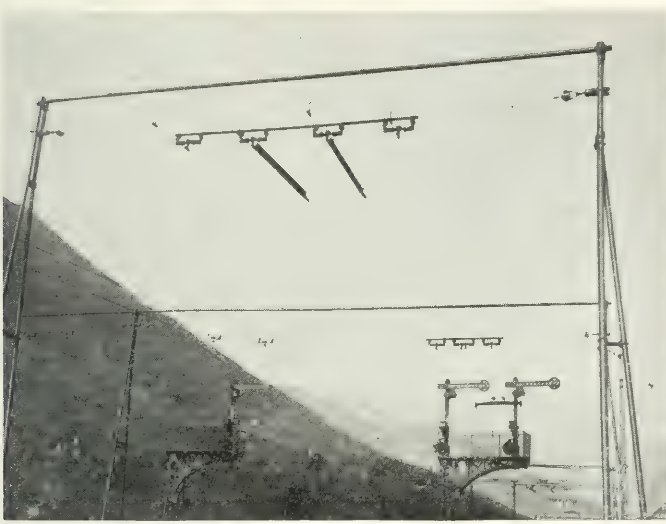

FIG. 13—DETAILS OF OVERHEAD CONSTRUCTION ON SIMPLON ELECTRIFICATION AS MODIFIED AT A SWITCH

One wire above each converging track is insulated for a sufficient distance to preclude the possibility of short-circuiting the phases. The same principle is employed in connection with the three-phase systems previously described but is somewhat more complicated where the catenary type of construction is used.

The good results obtained with the type of overhead construction used on this road are, in the opinion of the writer, largely due to the design of the bow trolley. Two small auxiliary bow trolleys are mounted on a large bow. Each of the auxiliary bows is pressed independently by springs against its contact wire; in this way great flexibility is obtained both through the smaller inertia of the individual bows, and also because the use of a separate collector for each

wire obviates the necessity of having the two wires at exactly the same level. In one respect this construction is not quite as safe as that of the Giovi locomotives, since with the two auxiliary pantigraphs there is greater possibility that, when the locomotive sways, one collector may slip off the wire, while in the case of the Giovi locomotives the collector is mechanically constructed as a continuous cylinder, the two metallic sections for the two wires being separated by a section of hard insulating material which prevents them from becoming lodged. No difficulty has been experienced with the Simplon locomotives on this account, however, since the spacing used in the overhead construction and the width of the the bows is such that the sway can be considerable before one of the wires will be able to leave its bow. Moreover, the overhead construction is not installed as high as is customary in American practice. The customary distance between wires for three-phase railways operating at 3 000 volts is about two feet and the width of one bow may be as much as about eighteen inches. Of course any three-phase overhead construction has to be installed carefully and intelligently to give the satisfactory results that have thus far been realized on European roads.

It will be seen that the overhead work, in spite of being three-phase, is in this case very simple, especially if it be considered that Fig. 13 represents the construction over a switch and about the most complicated looking part of the installation. The arrangement of the circuits at switches and crossings to prevent short-circuiting of the phases may also be seen by referring to this illustration. At a point where the collector would be in danger of bridging both its own wire and the adjacent wire of the other phase belonging to the other track, two strain insulators are inserted. From these the two inside wires, each corresponding to a different phase, are carried to an insulating bar inserted between the two outside wires at a point approximately above the place where the tracks cross or join, as the case may be. These short sections of the overhead circuits are therefore dead, and, while the locomotive is passing this point, the motors will receive only single-phase current if only one of the double trolleys is being used. In the event that a locomotive may require polyphase power when it is under one of these sections, as for starting, contact may be made with both overhead phases by raising a collector at each end of the cab, one of the collectors being always outside of the dead portion.

THE JOURNAL QUESTION BOX

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Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

439—Improving Plant Operating Conditions—We have about 5 000 hp in motors ranging in size from 5 to 450 hp. These motors are running at about 50 percent of full load. All the motors are 25-cycle, 400 volt, three-phase and operate at comparatively low speeds. The 300 hp motors run at 480 r.p.m.; the 5 hp at 720 r.p.m. Part of the time the motors operate at not over 70 percent of full load except about two 75 hp machines, which run near full load. The power house generating capacity is four 810 kw generators, rated speed 107 r.p.m. These generators, on account of engine difficulty, are run at 27 cycles or 115 r.p.m. approximately. The engines are gas engines and are very unstable as to regulation and will not carry a load of over 700 kw on the generators. They often do not give stable operation on over 500 kw. The feeder mains from switchboard to motors are amply large and the voltage drop at the motors will be five percent and less. What is the necessary voltage to carry at power house to operate the plant most economically and why? Under the above conditions what should be our generator and motor efficiency and the power-factor of the line system? What is the effect on efficiency, power-factor, and ampere load of the motors and generators to operate at, say, ten percent below and ten percent above normal voltage; ten percent below and ten percent above normal frequency at the above load factors? When we operate the generators at 115 r.p.m. with the alternating current voltage at 410 to 425 and a change of running conditions occurs such as putting on a motor or bad ignition on an engine, the generators often drop their entire load, excitation and all; the alternating current and consequently direct current immediately drops, no amount of quick action serving to save the load. The excitation is by a motor-driven exciter set of 75 kw capacity which at night carries full load and often a little overload, the addition being the power house lights. Why do the generators lose the load? Is it on account of the excitation point of the generator fields being low on the point of the saturation curve? Please give information covering the points noted. E. J. S.

To answer all the questions in the above completely would require more space than is at our disposal. The following answers a part of the questions raised. Increasing or decreasing the voltages of an alternating-current plant makes but little difference with the efficiency of the plant operation so long as the voltage changes are relatively small and the motor loads remain approximately the same. Increasing the voltage tends to increase the iron losses of both generators and motors, while at the same time the energy current is reduced, thereby reducing the copper losses both of the generators and motors. Reducing the voltage, on the other hand, increases the copper losses and decreases the iron losses. At normal voltage and full load the increase of loss due to one of these effects is nearly counter-balanced by the decrease due to the other. So far as power-factor is concerned increasing the voltage at the motors increases the exciting current taken by each motor; in other words, the wattless element taken

by the motor is increased while at the same time the watt element is decreased. The effect of such an increase in voltage is therefore to decrease the power-factor of the load taken by the motors. Thus, variations in voltage in a plant of the character described will have but little effect on the efficiency while the power-factor of the load will in general decrease as the voltage increases and vice versa. The explanation of the loss of load in the above question is undoubtedly the instability of the exciter. Any direct-current machine has an unstable equilibrium at points in its saturation curve below the knee. If operated at points above the knee it is stable unless a sudden speed variation drops the voltage to a point on the saturation curve below the knee. In this latter event the voltage will continue to drop until it has disappeared entirely. This latter is undoubtedly what happens in the case cited. A sudden decrease in speed, caused either by an increase in load or a failure to explode a charge in a gas engine, causes the exciter voltage to drop to a point below the knee on the saturation curve. From this point down to zero the system is in unstable equilibrium and the result is a continued decrease in exciter voltage until the load is completely gone. The cure for this condition is either to excite from some source whose speed is independent of the speed of the main units or to use a Tirrill regulator upon the present exciter. In the latter case it will be impossible to do lighting from the same source. The effects of variations of voltage and frequency on the performance of induction motors is outlined in an article by Mr. G. B. Werner in the JOURNAL for July, 1906, p. 400. The effect on the efficiency, power-factor and ampere load of the motors and generators of a system of operating at a variation of voltage of from, say, "ten percent below and ten percent above normal voltage" with given load factors, is outlined in an article by Mr. V. Karapetoff, on "Applications of Alternating-Current Diagrams," in the JOURNAL for Oct., 1904, p. 532. See also a study of the performance of the induction motor as given under "Characteristic Curves," in article by Mr. A. M. Dudley, in the JOURNAL for July, 1908, p. 367. P. M. L.

440—Effect of Connection on Power-Factor of Polyphase Motor.— Given a three-phase motor operated *a* from two transformers connected in open delta or V, *b* from three transformers connected in closed delta, will the power-factor of the circuit be the same in both cases, assuming the power-factor of the motor to be constant? L. A. S.

In the V-connected group of transformers, the current taken by phase *C* must flow through the impedance of two transformers, rather than that of one, as in phases *A* and *B*. This leads to an unbalancing of the voltage of the secondary side and of the current on the primary side. The power-factor of phase *C* will be different from that of phases *A* and *B*. Therefore it might be said that the power-factor of the group will be different from that of a delta-connected group of transformers. However, since the impedance of the transformers is only a part of that of the total circuit, the unbalancing is not as great as might be supposed at first sight. Note articles by Messrs. Soule and Stone in the April, 1910, issue. E. G. R.

441—Division of Load in Transformer Bank—Three transformers one of 75 kw and two of 25 kw capacity each, were connected delta to delta, stepping down from 6 600 to 2 200 volts. One of the smaller transformers became so overheated that it was necessary to disconnect it. This bank of transformers supplied several small induction motors and a considerable lighting load. *a*—Does the load on such a bank of transformers tend to divide evenly among them, thus exceeding the capacity of the smaller ones and thereby causing overheating? *b*—If this is the case, would three transformers of unequal size operate satisfactorily in delta if the capacity of the

smallest was equal to at least one-third the total kw? *c*—If two transformers, say of 40 kw each, are in open delta, and two 20 kw transformers are connected in multiple across the third phase, would the arrangement give satisfactory service? *d*—If two transformers of unequal size are connected in open delta, would there be a serious unbalancing of secondary voltages? G. W. W.

a—In any delta group of three three transformers, two paths are open to the current of a given phase, viz., through transformer *1*, and through transformers *2* and *3* in series, the latter two being parallel with the first. The currents will then divide inversely as the impedances of these two paths and the total current in each transformer will be the resultant of the currents from all three phases in that transformer. (See article by Mr. E. C. Stone, in the April, 1910, issue.) In the case at hand, the group of transformers is carrying, besides a balanced three-phase load at fairly low power-factor (motors), a considerable single-phase load at high power-factor on one phase (lamps). The combination produces a distortion of current in the transformers, which very materially overloads one of the smaller ones. This will always be the case when the single-phase load is of different power-factor than the balanced three-phase load. A better arrangement would have been to use three transformers of equal size and to divide the lighting load equally between the three phases or, what would be more satisfactory, to use a separate transformer for the lighting load.

b—This question cannot be covered by a general answer. Satisfactory operation would depend upon the nature and the distribution of the load and upon the impedances of the transformers. It would be better to use three transformers of equal size and distribute the load equally on the three.

c—The impedance volts (i e., volts necessary to drive full load through the transformer with secondary short-circuited) should be measured on the two 20 kw transformers in parallel, and also on one of the 40 kw units. If the values of voltage thus obtained are not widely different, the combination can be used as suggested.

d—The unbalancing of voltages would depend upon the difference in size of the two transformers. It is probable that two transformers, one of 25 kw and the other of 30 kw capacity, could be satisfactorily operated together in open delta, while, if the respective units were of 10 kw and 50 kw capacity, the voltages would be badly unbalanced. In general, the open delta should be avoided wherever possible. E. C. S.

442—**Rotary Converters Paralleled on Direct-Current Side** — Will two rotary converters which obtain their power from separate alternators run satisfactorily when connected in parallel on the direct-current side? B. L.

If the characteristics of the two rotaries are the same, they should run satisfactorily in parallel. Whether or not they will divide the load evenly at all loads depends upon the similarity in design of the two machines, the setting and condition of the brushes and the relative line drop in case the alternators are located at a distance. See No. 436. J. B. W.

443—In the article on "Self-Starting Synchronous Motors," which appeared in the JOURNAL for June, '09, p. 347, it is stated that if the field circuit is opened during starting, the voltage in the field winding will be raised to a dangerous value. Would this occur if the field circuit of an ordinary synchronous motor were opened after it had been connected and synchronized with the main line?

When the revolving field is rotating in synchronism with the armature field, there will be no e. m. f. induced in the field coils of a polyphase synchronous motor. The voltage is induced in the field coils on account of the relative rotation between the two fields. However, if the motor is loaded and the field circuit is opened, the

motor will drop out of synchronism and the conditions will be the same as during starting. J. B. W.

444—Skin Effect—In making the calculations for voltage drop and energy loss in alternating-current transmission lines, what would be the effect of using stranded cable instead of solid conductor; e. g., six No. 0 wires in the form of a cable vs. solid wire of the same area? J. L. S.

The following formula for skin effect is given in one of the electrical engineering handbooks:—

$$r = R\left[1 + \frac{1}{12}\left(\frac{2\pi\, fl}{R\times 10^9}\right)^2 - \frac{1}{180}\times\left(\frac{2\pi\, fl}{R\times 10^9}\right)^4 + \cdots\right]$$

where r=apparent resistance (with alternating current), R = real refrequency in cycles per sec., l= sistance (with direct current), f= length of conductor. The increase of resistance due to skin effect obviously depends on the factor $\frac{2\pi\, fl}{Rx10^9}$ of this formula and for any given frequency this varies as $\frac{1}{R}$. But for a given material (e.g., copper) having a specific resistance equal to S and a cross-section equal to A, the value of R may be expressed in terms of these quantities; i. e., $R = l\frac{S}{A}$. Then $\frac{1}{R} = \frac{1}{l\frac{S}{A}} = \frac{lA}{lS} = \frac{A}{S}$. Assuming a certain total cross-section of conducting material, the effect of arranging this material in the form of a cable consisting of separate wires or strands is, of course, to increase the diameter of the cable over that of the corresponding solid conconductor, which, so far as the skin effect is concerned, is equivalent to substituting another material of higher specific resistance (res. per unit cubical section). The apparent increase in specific resistance is proportional to the increase in apparent cross-section of the cable over the real total cross-section of the respective wires. Hence, $\frac{A}{S}$ and therefore $\frac{1}{R}$ remains constant and the ratio $\frac{r}{R}$ is unchanged regardless of the stranding (assuming uniform distribution of the conducting material throughout the section of the cable). Stranded cables having rope centers are sometimes recommended as a means of reducing the skin effect and thus increasing the conductivity on alternating current. In the case assumed in the question stranded cable of equivalent carrying capacity would be more easily handled than a solid conductor of 600 000 circ. mils. When large currents or considerable lengths of line are involved it is advisable to subdivide the circuits, as, above certain limits, increase in cross-section gives only a small proportionate increase in conductivity because of the action of the skin effect. The question of increase of impedence due to skin effect is practically negligible for ordinary calculations where only small lengths of line are involved, when the conductors are of a non-magnetic material such as copper or aluminum. In the case of magnetic materials such as iron, the skin effect may be a quantity demanding due consideration. In this connection note article on "Skin Effect," by Mr. W. E. Miller, in "Transmission Line Calculations," in *General Electric Review*, Oct., 1909, pp. 450-51, in which is given a curve showing the increase of resistance of conductors due to skin effect, taking care of the effect of permeability where iron or steel is used. H. M. S. AND R. W. A,

445—Determination of Transformer Temperatures by Increase of Resistance—Please give the method of obtaining the internal temperature of the windings of transformers during the process of drying, by measuring the resistance of the windings by the use of direct-current. R. A. G.

The rise by resistance is obtained by the method recommended by the Standardization Commit-

tee of the A. I. E. E., employing the following formula: Rise in degrees = $(238.1 + t)(R_2 - R_1) \div R_1$ where R_1 = initial resistance of the copper at t degrees C., R_2 = final resistance, and t = initial temperature of copper.

R_1 and R_2 are determined by Ohm's law, $R = E \div I$, in which R = resistance, E = voltage drop across the resistance, and I = current.

In using current for drying out transformers, care should be exercised to obtain accurate results, inasmuch as high temperatures are necessary to dry out the transformers and an error might result in damaging the insulation by *too high* a temperature. A measurement of the initial temperature of the coils should not be attempted when it is widely different from that of the oil in which it is submerged, but they should be allowed to reach a uniform temperature. For further information see article by Mr. R. E. Workman on "Factory Testing of Electrical Machinery," in the JOURNAL for Sept., 1904, p. 481, and the "Standardization Rules" of the A. I. E. E. W. N. C.

446—Measurement of Three-Phase Power—Please explain how a polyphase wattmeter can register the total kw output of a three-phase system when the two series coils are inserted in two of the lines and the two potential coils are connected respectively from the same two lines to the third line of the circuit, i.e., according to the standard method of connection? W. P. F.

Consider the current flowing out in the two lines in which the series coils are inserted and returning in the third line, to which both shunt coils are attached. This is a justifiable assumption, since the current in one line is always equal to the vectorial sum of the currents in the other two lines. It will then readily be seen that the sum of the two single-phase meter readings equals the total power in the circuit, as each meter indicates the product of the current in its line times the corresponding voltage. See article by Mr. R. E. Workman in the JOURNAL for Dec., 1904, p. 674; also article by Mr. H. M. Scheibe in the JOURNAL for Jan., 1907, p. 56. This method is equivalent to using a polyphase wattmeter, as the latter is composed of two single-phase wattmeters having their moving elements mounted on a common shaft and connected exactly the same as for two single-phase wattmeters. The true power of a three-phase, three-wire circuit or of a two-phase, three-wire circuit is measured by means of this connection regardless of power-factor. In a three-phase, four-wire circuit there is a return path for each of the outside lines independent of each other and accordingly the three wattmeter method or its equivalent (using three series transformers) must be used.

P. M.

447—Selection of Transformer Sizes—How is the size of transformers to deliver a given amount of energy to a three-phase system determined, using three transformers, and using two transformers? W. P. R.

With three single-phase transformers connected either in star or delta and delivering energy to a three-phase line, the size of each unit in k.v.a. is determined by dividing the total amount of power delivered by three. However, in case two units are required to operate in open delta and deliver the same amount of power each unit must have a k.v.a. rating equal to the total k.v.a. divided by $\sqrt{3}$, or, in other words, a rating equal to approximately 58 percent of the total power to be handled by the group. See article on "Rating of Single-Phase Transformers for Grouping on Polyphase Circuits," by Mr. H. C. Soule, in the JOURNAL for April, 1910, p. 298. See also Nos. 21, 53, 160 and 162. E. G. R.

448—Half Voltage Taps on Delta-Connected Transformers — If a three-phase load is placed upon a set of three transformers connected in delta by connecting this load to the respective middle points of the secondaries of the transformers in order to obtain

a voltage equal to one half of the normal secondary terminal voltage of the transformers, could any abnormal conditions arise which would cause this load voltage to become greater than normal? W. P. A.

If one phase only is loaded, the e.m.f. will fall on one side of the taps from which the load is drawn and will rise on the other side, with certain types of transformers this unbalancing might be very considerable. A similar effect may occur where the phases are unequally loaded or the power factors of the phases are widely different. E. C. S.

449 — Reduction of Fire Risk in Connection with Oil-Insulated Transformers—*a* What possibility is there of the oil in oil-cooled power plant transformers becoming ignited from short circuits or lightning flashes and how serious would be the resultant fire? *b*—If the transformers are of the standard type with cast iron covers, would the flame be smothered or would the cover be destroyed so that the flames could reach higher? *c*—Is it common practice to provide some means of preventing damage due to such fires in power plants or transformer sub-stations? If so, what methods are employed? *d*—Is is good practice to have a means of emptying the transformer cases by means of pipe lines leading from the valves at the lower part of the case to some point outside the building? R. F.

a—Transformer oil can only be ignited by heating it to its fire point which means a temperature at which it will burn, usually ranging from 175 to 200 degrees C. If transformer oil which is approximately within this temperature range is exposed to an arc, the oil will probably take fire and burn if sufficient air supply is provided. The seriousness of such a conflagration will be determined by the nature of the surroundings, the volume of oil involved, the character of the transformer case and the importance of a failure in the service, as well as other local conditions. A fire proof building with means for extinguishing the fire and withdrawing the oil offers much less risk than a frame building with no means of fighting the fire nor of disposing of the oil. Modern transformer tanks are strong and fire resisting, even to such an extent that the oil may be distilled out of them without destroying the tank. *b*—Transformers with cast iron covers and fire proof cases may generally be so closed as to smother any fire which may have been started inside of them. A wet blanket or tarpaulin for shutting off the air supply is a good way of extinguishing such an oil fire. *c*—The usual means of providing against fires of this kind, when anything is provided, is to have a tarpaulin at hand and sometimes a chemical fire extinguisher. The use of the latter will damage the oil, necessitating a treatment to remove the water and acid which will be thrown into it. *d*—A considerable number of modern stations are arranged for discharging the oil from their transformers in case of fire. In some of these cases the oil is dischaged into a sewer and in other cases it is withdrawn into tanks removed from the fire zone. The latter method seems preferable, although the chances of fire are extremely remote in a modern transformer and the expense of such a piping system is questionable; however, in some instances it may be desirable. An example of a satisfactory method of handling this problem in connection with a modern large power station is given in an article by Mr. L. T. Peck in the JOURNAL for Dec., '07, pp. 671-2. K. C. R.

450—Trouble with Induction Motor Auto-Starter Transformers—Power is supplied throughout practically 24 hours a day to a 150 hp, 60-cycle, 200-volt, two-phase induction motor, direct-connected to a 100 kw, 250-volt, direct-current generator. Recently, after operating for about 12 hours, under full-load, a coil of one of the auto-transformers

burned out. How could this happen when the set had been in constant operation and the circuit breaker had not opened, thereby necessitating re-starting? Is not the auto-transformer disconnected from the circuit except during the process of starting? I. F. D.

The connections of the auto-starter switches are such that during normal operation each transformer is disconnected from the line at one terminal, the other terminal being permanently connected to the middle line of the two-phase, three-wire circuit. Thus, the line voltage is impressed on the coils of the auto-transformer notwithstanding the fact that they are partially disconnected, and there is consequently a constant voltage strain to ground. Accordingly, in case of failure of the insulation to ground a burn-out such as that noted in the question might develop. Another possible source of trouble is that which might arise from break-down between the switch contacts which, if provided, disconnect the auto-transformers from the line when they are not in service. The latter condition would, of course, cause line voltage to be impressed on the auto-transformers and, as they are ordinarily designed for only intermittent service a burn-out might develop. F. H. L.

451—**Unbalancing in Transformers Arranged for Three-Phase—Two-Phase Transformation**—*Power is supplied from a generating station to a rotary converter sub-station via a 19-mile, 10 000 volt, three-phase transmission line. At the power house is a bank of three 100 kw, 2 300/10 000 volt transformers, while at the sub-station there are two 150 kw, 10 000/436 volt step-down transformers arranged for three-phase—two-phase transformation. These transformers are connected to a 600 volt, two-phase, six-pole, 25-cycle rotary converter running at 500 r.p.m. Are the currents taken by the respective transformers at the power house equal to one another at various loads, with this method of connection; if not, what amount of current should each transformer take, assuming a load of about 60 percent of the full load capacity of the transformers and a power factor of 100 percent on the rotary converter?* W. F. H.

All synchronous apparatus is especially sensitive to any unbalancing of impressed voltages. Since the regulation is different on each of the transformers of the three-phase—two-phase group, it will cause unbalancing in the rotary converters. This will result in unequal currents in the respective transformers and likewise in the respective phases of the 19-mile transmission line which will emphasize the effect. The result is that the current in the three transformers at the power house will probably be slightly different, but unless some abnormal condition is present, the unbalancing should not be sufficient to interfere with satisfactory operation. Calculation of the exact currents of the three transformers is very complicated and involves the constants of both step-up and step-down transformers, and of the line and rotary converter. F. C. S.

452—**Calculation of Power Factor**—*How may the power factor of a three-phase system be calculated from ammeter, voltmeter and wattmeter readings? Can the method be applied regardless of the power factor and is it applicable alike for balanced and unbalanced conditions?* W. F. H.

The sum of the three values of current multiplied by the line voltage (or the mean voltage, if the voltages of the three phases differ slightly) divided by 1.732 (to obtain the equivalent voltage to neutral) gives the three-phase volt amperes. The average power factor equals the true watts (as measured by a wattmeter) divided by the volt amperes. H. W. B.

453—**Y-Delta Connection of Transformers**—*Please give details of connections, proportional number of turns and uses of a method of transformer connection involving only two transformers which may be employed on a three-phase, primary, Y-connected circuit with neutral grounded or connected to the generator by means of a fourth wire, and giving three-phase voltage relations on the secondary side.* A. H. B.

This involves simply an ordinary V or open-delta connection. The two single-phase units are connected on the primary side between neutral and two outside lines across two phases of the circuit with one set of terminals reversed in order to obtain 60 degree (i.e., delta) voltage relations on the secondary side and 120 degree (Y) relations on the primary side. The ratio of voltages will be the same as though each transformer were connected as a single-phase unit. Thus, if the primary voltage is to be ten times the secondary voltage, the primary turns must be ten times the secondary turns. When connected in this way the full-load loss will occur when carrying 86.6 percent of full load, on account of the phase relations involved

E. C. S.

454—Loading Back Alternators for Testing—Please explain method known as "shifting the phase" used in testing similar alternators or frequency changes. B. L.

The method of "loading back" for the purpose of testing is probably what is referred to and is explained in the JOURNAL for August, 1906, p. 475, in an article by Mr. C. J. Fay, from which the following is quoted:—

"To avoid great expense in testing and equipment, 'loading back' methods are resorted to for testing large direct-current motors and generators and motor-generator sets of all kinds. Alternating-current generators and rotary converters are run open-circuited and short-circuited in testing, except in special cases. Induction motors are loaded by circulating current through the windings at low voltage." The loading back method is also applied to the testing of transformers. It consists, briefly, in connecting two machines in parallel in such way as that the voltages will be in opposition, full-load current or greater if desired, being circulated in the windings of the machines, the losses, only, being supplied electrically or mechanically from an external source.

455—Burned Spots on Commutator—The commutator of a 175 kw, two-phase, six-pole rotary converter has developed six burned spots, each covering the full length of about five adjacent bars and all spaced at equal intervals around the circumference of the commutator. The side of each burned spot toward the direction of rotation is uneven, but the trailing side of each terminates at one bar throughout its length. The machine has been running satisfactorily for a number of years, the load being about 185 kw. The commutator has been turned down twice within the last six months, as there is also considerable sparking at the brushes. However, the spots do not seem to be due to over-load as they have appeared within the last year. Could the trouble be due to a bad connection in the windings or collector rings? B. L.

If the trouble mentioned has appeared recently, we would look for the cause in some defect in the connections between the armature winding and the commutator. If the rotary converter is provided with a multiple winding with equipotential cross-connections, the most probable cause would be an open-circuit in some of these cross-connections. This is indicated by the fact that the blackened bars occur symmetrically with the poles. If there were any interruption in the main armature winding, there would, of course, be a pronounced flash as the commutator bars corresponding to the defective coil passed under the brushes. F. D. N.

NOTE

Information furnished in connection with the answer to No. 428 was overlooked until too late for correction. The statement in the first and fifth sentences relative to leading power-factor is not correct, the main disadvantage of operation of an induction motor above synchronous speed as an induction generator being that there is a wattless component which results in low power-factor unless compensated for by some extraneous source of leading current such as an over-excited synchronous machine.

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Rates for Electric Service

In the sale of electricity for light, two anomalous conditions have existed. First, the consumer buys light and pays for electricity; and, second, the consumer usually pays for the kilowatt-hours he uses, although the total cost to the central station for supplying this service is not proportional to the kilowatt-hours.

In the sale of light, a charge based upon the meter reading would be reasonable if there were a definite ratio between the quantity of light and the speed of the meter, but there is not. The light of the carbon lamp depends upon the quality of the electricity as well as the quantity; for a slight increase in voltage causes a small increase in meter reading but a relatively great increase in the light. It may be argued that if a consumer buys electricity he may use it as he desires, but in most cases he does not act independently, as the central station regulates the voltage and often supplies the lamps. Again, the tungsten filament lamp will produce two or three times as much light with the same current consumption as the ordinary carbon filament lamp. This change may be made by the consumer who, therefore, has it in his power to secure from the electric light company two or three times the amount of light without increasing his bill for current.

In the second place, the ordinary method of charging at, say, ten cents per kilowatt-hour, regardless either of the amount of the load or of the time of day when the load occurs, makes the income to the central station directly proportional to the meter reading; whereas, the large part of the cost of supplying the service is in fixed charges for apparatus and circuits, and in certain of the operating expenses which are independent of the meter reading. It is well known that in residence lighting, the total cost to the central station would be but slightly changed if a consumer who has fifty lamps were to burn only one instead of fifty. Interest, taxes, depreciation and all day losses would be practically the same.

The uniform rates have been so fixed that with the ordinary use of current for carbon lamps, the returns are sufficient to cover

the total cost, including the various fixed charges and the cost of fuel for producing the current. In some cases the part of the cost which is independent of the amount of current used may be a large percent of the total cost. Now, if some new condition arises, this artificial uniform rate is no longer a fair and just one. For example, if one consumer by changing his lamps secures the same amount of light with half the current consumption, then the cost to the central station may be reduced but slightly, although the revenue has been cut in two. On the other hand, if another customer uses his light twice as long or places fan motors, irons or toasters on his circuits, his bill may be doubled although the cost to the central station has increased but little. The high rate restricts the use of current. A ten-cent rate might be prohibitive, where a five-cent rate would cultivate a day load which would be more profitable to the central station than the ten-cent rate during the peak load. Hence, the single definite rate which may have been fairly determined for one kind of service, may be quite unfair in other cases, the unfortunate party being sometimes the central station, sometimes the consumer, and sometimes both.

These common and simple conditions are well known. They are brought into especial prominence when any new condition arises.

One of these conditions during the recent years has been the day-load, brought about by motors on central station circuits. The advantage of a load for eight or ten hours a day instead of an hour or two in the evening soon brought about special rates for motor loads. On the other hand, the increase in the introduction of tungsten lamps calls for a new adjustment of a somewhat different kind.

A timely paper by Mr. S. E. Doane before the St. Louis convention of the National Electric Light Association deals with the subject from the standpoint of the central station and the tungsten lamp. He divides the cost to the central station into the consumer cost, which the individual consumer causes whether he uses current or not; the demand cost, which provides the equipment and organization ready to supply current, and the output cost, which includes fuel and other items depending upon the kilowatt-hours generated. He secured data from many central stations, and found that on the average the consumer cost is 15 percent, the demand cost 55 percent (making a total of 70 percent which is independent of the load), and the output cost 30 percent. Hence, a reduction of two-thirds of the output of a company in current (and of the income in cash), would be accompanied by a reduction of only 20

percent in total expenses, leaving them 80 percent of what they were at first. Hence, the central station would be in the sad plight of having one-third its income with a reduction of only one-fifth in its expenses. In fact, a condition of this kind might result from the sudden introduction of a highly efficient lamp. This would leave a large part of the plant virtually idle. There may be in time, an increase in business from the acquiring of new customers or the development of new kinds of load which will enable the whole plant to be operated. Sudden extremes are not liable, but the conditions presented by Mr. Doane merit active study, and an aggressive campaign for day load.

The problem is by no means a simple one; and the varying conditions require various solutions in different places. The problem is complicated when it is simply the commercial one of determining the different elements which make up the actual cost of affording service and of supplying power in varying quantities and at different times, and determining a practical scheme of charges which will be fair to both central station and consumer. These, however, are not the only elements, for cost alone is only one factor, there remains a profit to be provided for.

The relations are not merely business relations, but they usually involve the principle of public service. A community has certain needs in common, such as a supply of water, gas, electricity or street car service which, in general, cannot be supplied by the individual for himself, but must be furnished to the community in common. Shall this service be conducted by the community itself through its government, or shall it be supplied by some individual or corporation? If by the latter method, a grant of rights to use the streets for pipes or wires or tracks must be given. Is the company having these rights, which inherently constitute a monopoly, at liberty to use its exclusive opportunities for exorbitant charges and inordinate profits; or is it a servant of the community engaged in a public service and entitled to a fair profit? Granting that the latter position, which is growing in popular favor, is the correct one, the question then arises, What are the actual costs and what is a fair profit? Simple as these questions may appear before they are studied, they become very difficult of solution as they become more thoroughly understood.

The review of the Madison Case in this issue of the JOURNAL presents this problem in a luminous manner which is of importance not merely for the particular conditions presented, but also as a clear

statement and a definite solution of a fundamental problem which will receive far more attention in the future than it has in the past. While there are serious evils to be overcome, there are others to be avoided. The effect of definitely fixing maximum returns may, on one hand, tend to repress enterprise and efficiency; while, on the other hand, a reasonable protection and a reasonable guarantee of an adequate return for efficient service may be attractive features to conservative investors. It may work something of a hardship to allow no "going value" to an effective organization, since a successful business is not always obtained by the mere spending of the money which appears in the physical plant. The question of what may be termed the original "hard-luck" percentage in developing a plant is also liable to exist, although difficult to recognize in subsequent estimates of value.

The question of the rates which should be charged for electric service is one of foremost importance from the commercial standpoint of extending the use of electric current on a basis which will be fair both to the central station and the user under the varying load factors and other conditions, and also on a basis of equitable relationship between the public service corporation and the community.

CHAS. F. SCOTT

The Scientist and the Engineer

No thinking man can deny that a very large proportion of the material comforts and advantages which form so large a part of our modern civilization are due to the work of the scientist and of the engineer. The results of their work have been so far-reaching during the last few decades, and our present progress is so rapid, that our imagination fails us when we attempt to predict the advancement possible by mankind. All that has been accomplished is largely due to the men who have been able to facilitate transportation and communication, to produce better and cheaper materials, to give us improved tools and to utilize in a practical way many of the forces of nature which a hundred years ago were of little or no use.

It might be a question whether modern methods and modern tools are capable of producing better sculptures than those of twenty centuries ago, but there is no question whatever that these same tools, directed by the scientifically trained engineer, do produce innumerable comforts and advantages which make for "a higher humanity and more godlike race."

The relation of the scientist and the engineer to modern progress is admirably presented by Dr. L. H. Baekeland, in his address on "Science and Industry," extracts from which are given on another page. A personal word about Dr. Baekeland may be of further interest. It may not be known to the majority of the readers of the JOURNAL that Dr. Baekeland is the inventor of developing paper of the Velox type which, together with the dry plate, has completely revolutionized photographic processes and put in the hands of tens of thousands of amateurs the means of making photographs of a grade and under conditions which would have been absolutely impossible by the methods of two or three decades ago. Dr. Baekeland has also been closely identified with the great electro-chemical development in and about Niagara Falls, and his latest invention, "Bakelite," promises to revolutionize many manufacturing processes which are now considered as standard.

All who are interested in a broad view of the effect on human progress of the work of the scientist and the engineer cannot read Dr. Baekeland's address without getting a clearer vision of the forces which underlie our modern civilization, and feeling an inspiration to larger individual effort. C. E. SKINNER

Water Power Rights

The National Electric Light Association has established a power transmission section for considering not only the engineering and operating features of electrical transmission, but also the legal problems and public policies. Waterpower development has become a leading economic and political question, as well as an engineering problem. These new questions did not exist ten years ago. They follow the work of those who have developed electric power transmission, both transmission engineers and transmission financiers. There is a tendency in dealing with these questions to consider some specific point, or some particular law or individual case; on the other hand, it is one of the broadest questions which presents itself not only to those interested in transmission but to all people of the present time.

The relation of our government and laws to water power development is commanding general attention. Engineering development during the past century has led the legal development. Our fathers who drafted the wonderful Constitution of the United States were wise, but they could not foresee all that was coming. They provided for the regulation of commerce between the States,

a generation or so before the locomotive made its appearance. They made provisions for establishing post routes fifty years before there were mail trains or postage stamps. They established principles, and it has been the function of our Supreme Court to develop the application of these principles to modern conditions. The Constitution follows the engineer.

With regard to water powers and their use, the laws are antiquated; many of them were made before power transmission was thought of. At the St. Louis convention of the Association it was stated that some of the laws now in force were passed in the '60's, about the time of the invention of the modern dynamo, and the discovery of its reversible action which makes it a motor.

In an address on conservation by Mr. J. H. Finney, at the recent convention of the American Electrochemical Society, the complicated problem of legal relationship was shown to involve a number of fundamental questions in our government, such as the relation of the State to the general Government, particularly with reference to the jurisdiction in the case of rivers which are entirely in one State or flow from one State to another, or which form the boundary line between two States. There are also questions of the relation of the individual to the community and the relation between private and public ownership and rights.

These are questions which concern public service corporations of all kinds. At the Electric Light convention there were addresses by prominent men in which a remarkable sympathy for the principle of government control of public service corporations was expressed and was apparently endorsed by the convention, although the sentiments would doubtless have appeared very radical five or ten years ago. In this question the public is concerned not so much with legal rights as with moral rights. Not rights in the narrow sense, but in their broad relations. Here are our natural resources; how can they best be conserved to the public? The public, as much as any individual or company, desires to see our water power developed, but they are right in wanting this development to be upon a fair and just basis. We should deal with these large and fundamental problems, not as particular cases, but in accordance with broad principles, and in such a way that in coming years, when the importance of these questions becomes greater and greater, it will be found that the solutions which we may now make will have been the correct ones.

In the discussion above referred to, it was mentioned that the

laws relating to water rights in the East were not adequate in the West, where the possible use of the water was no longer restricted to the narrow strip of land along its course, but was needed for irrigation over large areas. Hence, the needs of those at a distance were recognized as constituting rights which were framed into irrigation laws.

An analogous condition exists in the case of power. So long as the power from a water wheel could not be carried more than a few hundred feet, people at a distance had no particular interest in power rights. When, however, electric transmission supplied the means for distributing power for the needs of distant communities, then the public asserted an interest and a right in the use of nature's bounty.

The principles which should underlie the policies in the conservation and use of water power cannot be determined by antiquated and inadequate laws, but must shape themselves in accordance with new conditions with a full recognition of the fundamental rights of the people in natural resources, and of the new public interests and rights in water power which have been created through the transmission and application of power by electricity.

CHAS. F. SCOTT

Keeping Departments in Synchronism

The paper by Mr. Paul Lüpke on "Super-Specialization," extracts from which appear in this issue of the JOURNAL, deserves careful reading by all of us, but more particularly it merits careful after-consideration. It applies too well to employees of large organizations where the tendency is for individuals to develop narrowness; perhaps through selfish motives, sometimes through petty personal dislikes, but more often due to the ease with which one can excuse or cover up the results of a failure to do their whole duty. All those who are connected with large enterprises, having many departments, each with its own interests, which may seem to conflict with those of other departments, but which in reality by analysis can be made to work together to the common good of the complete organization, will fully comprehend just how nicely this paper applies to their everyday work. It is to all such that this paper is earnestly commended.

C. W. JOHNSON

THE ELECTRIFICATION OF RAILWAYS*

AN IMPERATIVE NEED FOR THE SELECTION OF A SYSTEM FOR UNIVERSAL USE

GEORGE WESTINGHOUSE

As an illustration of the wonders of the laws of nature, few inventions or discoveries with which we are familiar can excel the static transformer of the electrical energy of alternating currents of high voltage into equivalent energy at a lower voltage.

To have discovered how to make an inert mass of metal capable of transforming alternating current of 100 000 volts into currents of any required lower voltage with the loss of only a trifle of the energy so transformed, would have been to achieve enduring fame. The facts divide this honor among a few, the beneficiaries will be tens of millions.

IN less than twenty-five years a new industrial and economic situation has been created by the development of apparatus to generate, distribute and utilize electricity. Not less than two thousand million dollars have been invested in plants to manufacture apparatus, in power houses to generate electricity, in lines of copper wire to transmit this mysterious energy, in construction of railways and their equipment and in the manufacture of products unknown before the advent of electricity. Large sums have already been spent in the electrification of portions of standard steam railways in England, continental Europe and America, and there is now available a fund of information of inestimable value to guide those charged with the selection of an electrical system for railway operations.

The president of our brother Institution of Mechanical Engineers, Mr. Aspinall, in his presidential address delivered April 23, 1909, placed the railway world under deep obligation for most valuable information upon the electrical equipment and operation of trains of the Lancashire & Yorkshire Railway, of which he is the worthy and skillful general manager. His observations on the effects of low center of gravity and heavy, inflexible motor trucks upon the permanent way are especially valuable in that they direct attention to costs which at first were not considered with sufficient care.

Believing unreservedly that the increased capacity of a railway and its stations, the economies of operation, and other advantages

*A paper to be presented before a joint meeting of the American Society of Mechanical Engineers and the Institution of Mechanical Engineers to be held in London, July, 1910.

will bring about gradually the systematic electrification of steam railways, my wish is that the progress of the art may not be hampered and such electrification of our main lines delayed or rendered unprofitable by mistakes which experience, judgment and foresight may enable us to avoid.

It is my intention in this paper to direct attention to the necessity for the very early selection of a comprehensive electrical system embracing fundamental standards of construction which must be accepted by all railway companies in order to insure a continuance of that interchange of traffic which, through force of circumstances, has become practically universal, to the great advantage of transportation companies and of the public.

Although the facts clearly show the contrary, there exists a popular impression that the electrification of railways is a simple matter. and that it requires only decision by boards of directors to insure the immediate substitution of the electric for the steam locomotive.

The great difficulty in the electrification of standard railways is no longer in the engineering problem of developing a locomotive and an electrical system which will operate the trains, but it is a broad question of financial and general policy of far-reaching scope, considering the future electrification of railways in general as distinguished from isolated cases of limited extent, and requiring a combination of the highest engineering and commercial skill.

GAUGE OF TRACK AND INTERCHANGE OF TRAFFIC

In the first days of railway electrification, there was probably no idea of an interchange of traffic involving the use of the engines and cars of one railway upon the lines of another railway. It then made no difference whether the gauge of the track was 4 feet 8½ inches, the one ultimately selected, or one of a greater or lesser width by a few inches. The gauge selected by Stephenson was a practical one, fortunately, since it has become almost universal, with a strong probability that it will one day be absolutely so.

In 1878 there were in the United States eleven different gauges of railroad tracks in addition to the standard gauge of 4 feet 8½ inches. The absolute necessity for uniformity of gauge of tracks both in the United States and Canada became so apparent that in due course all of the roads which had gauges wider than 4 feet 8½ inches changed to the present standard. Among the remarkable achievements of engineering was the change of the tracks of an

entire system of railway of some hundreds of miles within twenty-four hours, this change having, however, required months of preparation. The losses entailed in the change of gauge and of equipment have ever since been serious burdens to most of those railways, in that the costs were in most cases covered by capital charges. It may be conceded that, so far as steam railway operation is concerned, there are now no obstacles to the interchange of traffic in the broadest sense, except in the size of vehicles in certain countries where the cost of changing tunnels and bridges would be prohibitive.

REQUIREMENTS FOR INTERCHANGE OF TRAFFIC

With these preliminary remarks I feel certain you will agree that to insure interchange of traffic, the fundamental requirements, so far as operation by steam is concerned, with full regard for safety, speed and comfort, are very few in number and are covered by the following:—

a—A standard guage of track.

b—A standard or interchangeable type of coupling for vehicles.

c—A uniform interchangeable type of brake apparatus.

d—Interchangeable heating apparatus.

e—A uniform system of train signals.

The additional fundamental requirements for electrically operated railways are:—

f—A supply of electricity of uniform quality as to voltage and periodicity.

g—Conductors to convey this electricity so uniformly located with reference to the rails that, without change of any kind, an electrically fitted locomotive or car of any company can collect its supply of current when upon the lines of other companies.

h—Uniform apparatus for control of electric supply whereby two or more electrically fitted locomotives or cars from different lines can be operated together from one locomotive or car.

DEVELOPMENT OF ALTERNATING-CURRENT APPARATUS

Having acquired a considerable experience in the introduction upon railways of the compressed air brakes and in the development of automatic electro-pneumatic signals, I was led in 1885, because of its general analogy to operation with which I was familiar, to interest myself in the American patents of Gaulard and Gibbs (a

Frenchman and an Englishman), covering a system of electrical distribution by means of alternating currents, with static transformers to reduce these currents from the high voltage necessary for economical transmission of electrical energy to the lower voltages required for the operation of incandescent lamps and for other purposes.

No inventions ever met with greater opposition in their commercial development than those relating to the generation, distribution and utilization of alternating currents, and it is a matter of record that the opponents of those interested in developing the alternating system even sought, through public meetings and the appointment of commissions, and by various extraordinary means, to influence and prejudice public opinion.

Realizing the limitations of the direct-current system, I became thoroughly convinced that the extended distribution of electricity for industrial purposes could only be secured by the generation of alternating currents of high voltage and their conversion by static transformers into currents of various voltages. Notwithstanding, therefore, the frank disbelief in its practical value of eminent scientific authorities, among them the late Lord Kelvin, I entered actively into the development of the alternating-current system of generation and distribution of electricity which is now almost universally accepted as the ideal. By 1888 Nikola Tesla had demonstrated the practicability of his induction motors, Oliver B. Shallenberger had perfected his meter for measuring alternating currents, and it had been proved that a direct-current motor with laminated armature and field could be operated either by alternating or by direct currents. I then became thoroughly imbued with the belief that further invention and discovery would in time make alternating-current apparatus practically universal for almost every purpose.

ELECTRICAL SYSTEMS FOR RAILWAYS

In the twenty years that have elapsed, three important electrical systems for the operation of railways have been put into practical operation, all using alternating current in whole or in part. These systems are:—

a—The direct-current system, usually spoken of as the "third-rail" system, which employs alternating current for transmitting power when the distance is considerable.

b—The three-phase alternating-current system with two overhead trolley wires.

c—The single-phase, alternating-current, high-tension system with a single overhead trolley wire.

In a notable case of the latter system, namely, that of the New York, New Haven & Hartford Railroad, the motors and controlling apparatus are arranged to utilize single-phase current from an overhead trolley wire at 11 000 volts, and also to be operated by current from the 650 volt third-rail system of the New York Central & Hudson River Railroad, thus making a demonstration of the wonderful flexibility of alternating-current apparatus. The problem before the officials of the New Haven road was not merely the electrification of a division of a few miles of its track, rendered compulsory by legal requirements, but the selection of a system which would meet the needs of a great railway covering several States, and having other congested centers of traffic which it might soon be desirable to electrify. In view of the fact that there had been no considerable demonstration of the single-phase system by actual use, and that the New Haven trains would be obliged to operate upon twelve miles of lines already equipped with the direct-current third-rail system, it must be conceded that the directors and management of the New York, New Haven & Hartford Railroad showed great courage and confidence in the judgment of their experts, and rendered to all other railroads a service of the highest character, when they selected the single-phase system for the electrification of the line mentioned.

The results of the working of the three-phase system in Italy and Switzerland have been very prominently before the world for several years, and its successful use there has been a material factor in the development of confidence in electricity for the operation of railway trains.

RAILWAY MOTORS

Essential requisites in a railway motor are that it shall start its load and quickly accelerate to the required speed, and that it shall operate continuously at any desired speed, or speeds. The three types of electric motors have certain fundamental differences in speed performance which are important factors in determining the advantages, disadvantages and limitations of the several systems.

The Direct-Current Motor—The characteristics of the direct-current series railway motor are well known. It automatically adjusts its speed in accordance with the load, running more slowly if the weight of the train be greater, or the grade steeper. The speed

with a given load, however, is definite; it is dependent upon the voltage applied to the motor and cannot readily be varied. It is true that the speed can be decreased by inserting a resistance in the motor circuit, but this is wasteful and is inadmissible except as a temporary expedient. It is true also that the motors may be connected in series, thus dividing the pressure between the two motors, and thereby reducing the speed one-half; or if among four motors, to one-quarter speed. As the system of current supply involves a fixed voltage, it is obvious that for emergencies no speed much above the maximum speed determined in the construction of the motor can be obtained. Furthermore, on account of the high cost involved in maintaining a practically constant voltage throughout the system, the voltage supplied to the motors often decreases considerably at the end of long lines, at the time of heavy load, thereby further reducing the speed attainable. It often happens in railway service that a locomotive should be operated somewhat above the normal speed, and sometimes a locomotive designed for freight service has to be pressed into passenger service. In such case the speed would be considerably less with the direct-current locomotive than that necessary to maintain the schedule speed. A special form of field control can be used in certain cases for varying the speed, although this has so far been utilized to a very limited extent.

The Three-Phase Motor—On the three-phase system, the motor is inherently a constant-speed motor; it runs at approximately the same speed at light load and at full load; it runs at nearly the same speed up a grade as on a level track, although the horse-power required on the grade may be several times that on the level. Conversely, it can run no faster on a level than it can climb a grade. In order to give a lower speed, however, the motors may be arranged upon the locomotive in pairs in a manner equivalent to the arrangement of two direct-current motors in series, just described. Motors may also be arranged for two or more speeds, but this involves some complication in windings and connections. In all cases lower speeds can be secured by the introduction of resistances which increase the losses and lower the efficiency. In no case can the speed in any of the arrangements of motors be appreciably higher at very light load than it is at full load.

The motors are of the induction type without commutators and their inherent limitations, and are of relative simplicity in construction. The current is usually supplied at 3 000 volts from two overhead lines through two sets of current collectors. With three-

phase motors as now constructed and arranged upon locomotives, it is possible with no additional complication so to utilize the motors when locomotives are moving trains upon a descending grade, that they become generators and return current to the line, a feature of value in certain mountainous districts, but not of controlling importance in the selection of a universal system.

The Single-Phase Motor—The single-phase railway motor is a series motor with speed characteristics very similar to those of the direct-current motor, as the speed at a given voltage is greater or less, depending upon the load. The speed with a given load is also greater or less, depending upon the pressure applied to the motor; and this is not limited, as with the direct-current motors, to that supplied by the circuit, and to one-half and one-fourth of that pressure, but is capable of adjustment to any degree of refinement by means of auxiliary connections from the secondary winding of the transformer on the locomotive, which is necessary for reducing the line voltage of 11 0000 volts to the lower voltage required by the motors. Not only may numerous voltages less than the normal be arranged for lower speeds, but higher voltages can be provided to make speeds considerably above the normal. In this simple manner a wide range of efficient speed adjustment is secured which is impossible with other systems.

Like the throttle lever of the steam locomotive, the control lever of the single-phase locomotive may be placed in any one of its numerous notches to maintain the required speed. This facility of efficient operation over a wide range of speed and power requirements is one of the especially valuable features of the single-phase system. This difference, however, may be noted; the ability of the steam locomotive to maintain its speed continuously with heavy loads depends upon the capacity of the boiler; on the other hand, the electric locomotive has an ample supply of energy available, drawn from a large power house, and the limit of its endurance is determined by the safe temperature of the motor.

The question of determination of the frequency for use on single-phase railways is one of very great importance. Twenty-five cycles is in general use for power transmission purposes and has been adopted by nearly all the single-phase railroads now operating. The Midi Railway of France has adopted 15 cycles. The lower frequency permits of a marked reduction in the size of motor for a given output, or conversely of a considerable increase in output from a motor of given dimensions and weight. Three-phase in-

stallations in nearly all cases employ approximately fifteen cycles. The choice of frequency is one of the most involved, difficult and important problems now presented for solution.

TRANSMISSION OF POWER FROM POWER HOUSE TO LOCOMOTIVE

The controlling factor in the cost of electrification in nearly all cases is the system for transmitting power from the power house to the locomotive, and not the locomotive itself. The choice between the several systems must, therefore, be based upon a comparison of the complete systems. The differences between the methods of transmitting power are of far greater importance than the differences between power houses or between locomotives. The current for all systems is generated in usual practice as high-tension alternating current, for the reason that electric energy can be most economically transmitted by high-tension alternating current, even though it is in some cases converted into direct current.

The Direct-Current System—For the direct-current locomotive the apparatus which intervenes between the alternating-current generator and the locomotive consists of a number of links or elements through which the electric energy must pass, one after the other. These consist of:—

a—Raising transformers in groups of three.

b—A transmission line of three wires; sub-stations, which require attendance, containing,

c—Transformers in groups of three, and

d—Rotary converters foı receiving the alternating current and delivering direct current.

e—A third-rail contact conductor, which for heavy work must often be supplemented by copper feeders.

f—The track return circuit, which must be provided with heavy bonds, and in certain cases supplemented by feeders and so-called negative boosters.

It is necessary to maintain the alignment of the third rail within close limits both in its distance from the track rails and in its elevation above them, as the contact shoe can have only a small range of automatic adjustment.

The Three-Phase System—For the three-phase locomotives the respective links between the generator and the locomotive are:—

a—Raising transformers in groups of three.

b—Transmission line of three wires.

c—Sub-station transformers in groups of three.

d—Two overhead wires as the contact system.

e—A track return which usually requires nothing but inexpensive bonding.

The two overhead trolley wires require a double system of overhead construction, as the wires must be kept separate and well insulated from one another; the two must be maintained at equal height above the track, and at switches and cross-overs the construction is complicated.

The Single-Phase System—For single phase locomotives there is:—

a—A raising transformer.

b—A transmission line of two wires and sub-stations widely spaced, each containing

c—A lowering transformer, which supplies

d—A single trolley wire.

e—A track return, usually requiring nothing but inexpensive bonding.

In certain cases where the distance from the power station is not more than 15 or 20 miles, the single-phase trolley can be supplied directly from the power house, so that only one single element, i. e., the trolley wire, intervenes between the generators and the locomotives. The single trolley wire permits a relatively wide range in height, as the pantagraph trolley automatically adjusts itself to the position of the trolley wire. In some cases the wire has a normal height of 22 feet, but is carried under bridges where the limit is 15½ feet.

The three types of railway motors, and the three respective systems for conveying power from the generating station to the locomotives, have all successfully demonstrated their ability to operate railway trains. It is not my purpose to urge the adoption of a particular system, but rather to point out some of the well-known characteristics of these systems which have a bearing upon their limitations and their general adaptability to railway conditions, and to urge the great gain which will result from a single universal system.

As the electrical manufacturing companies with which my name is associated manufacture and install all kinds of direct and alternating-current apparatus, I may be pardoned for saying that I have not permitted my judgment to be influenced by any personal material interests, and that I have treated this subject so as to give

others the benefits of a long experience, acquired under circumstances most favorable to ascertaining the facts.

REQUISITES FOR A UNIVERSAL ELECTRICAL SYSTEM

In selecting a proper electrical system for railway operation, it will probably be generally conceded that the following elements are of prime importance:—

a—The electric locomotive should be capable of performing the same kinds of service which the steam locomotive now performs.

b—The electric locomotive should be capable of exceeding the steam locomotive in its power capacity. The readiness with which several electric locomotives can be operated as a single unit enables any amount of power to be applied to a train.

c—The electric system should adapt itself to requirement beyond the ordinary limitations of the steam locomotive in small as well as large things. It should be adapted for use on branch lines, and for light passenger and freight service similar to that so profitably conducted by interurban electric roads, both in passenger and in express service.

d—A universal electrical system requires that power should be transmitted economically over long distances and supplied to the contact conductor. The system should utilize the most highly perfected apparatus for the electric transmission of energy and its transformation into suitable pressures for use.

e—The contact conductor in an ideal system should be economical to construct, both for the heaviest locomotives where the traffic is dense, and for light service on branch lines. It should impose minimum inconvenience to track maintenance; should give minimum probability of disarrangement in case of derailment, or in case of snow and sleet, and should in general be so placed and constructed as to give a maximum assurance of continuity of service.

The use now made of electricity in steam railway service has been brought about, generally speaking, through compulsion. The steam locomotive has reached its limitations and has been found unsuitable and inadequate in tunnels or in terminal service. Even where other considerations may have been controlling, the problem has usually been a specific one of electrifying a relatively small

area. The problem has been solved by considering those factors which were of immediate importance, without giving much weight to uniformity with other systems or of extensions. Now, the natural course of development will be the extension of these limited zones, until, after a time, they meet. Then there will arise great inconvenience and expense if the systems are unlike.

THE FUTURE OF ELECTRIFICATION OF RAILWAYS

The complete electrification of a railway will necessitate a rearrangement of ideas and practices in regard to operations. Coaling and watering places will not be needed; passenger trains will be differently composed, some classes being of less weight; and they will operate more frequently, thus promoting travel; other trains will be heavier than at present, or will operate at higher speeds; and branch lines, by the use of electrically fitted cars, can be given a through service not now enjoyed.

The movement of freight will undergo great changes, due to the fact that electric locomotives can be constructed with great excess capacity, enabling them to move longer trains at schedule speed on rising gradients.

The large percentage of shunting operations due entirely to the use of steam locomotives will no longer be required.

The railway companies can combine upon some coöperative plan for the generaton of electricity, thereby effecting large savings in capital expenditures; and can utilize their own rights of way for the transmission of the current, not only for the operation of trains but for many other useful purposes.

Notwithstanding the fact that great strides have already been made in cheapening the cost of generating electricity by steam engines, I foresee, from the progress made in the development of gas and oil engine power, a still further reduction in cost which will accelerate the work of electrifying existing railways. One important aspect of this great question will engage the thoughtful consideration of every government, namely, the military necessity for uniform railway equipment in time of war. There will be serious difficulties to surmount in the selection of a general system. There naturally will be arguments in favor of one or another of the systems now in use and the inclination of those who have adopted a particular system to advocate its general use. There will be enthusiastic inventors, and there will be many advocates of the common view, namely, that there is room for several systems and

that each system will best meet the requirements of a particular case. There will be those who give undue weight to some feature of minor importance, such as a particular type of motor or of locomotive, instead of giving a broad consideration to the whole system, and recognizing that in the general problem of railway electrification, facility and economy in transmitting power from the power house to the locomotive are of controlling importance.

Were there now only one system to be considered there would be a concentration of the energy of thousands on the perfecting and simplifying of the apparatus for that system, to the advantage of railway companies and of manufacturers.

In conclusion, I can only repeat, and earnestly recommend to the serious consideration of railway engineers and those in authority, the pressing need of determining the system which admits of the largest extension of railway electrification and of a prompt selection of those standards of electrification which will render possible a complete interchange of traffic in order to save expense in the future and to avoid difficulties and delays certain to arise unless some common understanding is arrived at very shortly.

THE SINGLE-PHASE SYSTEM ON THE NEW YORK, NEW HAVEN & HARTFORD RAILROAD*

The most important installation of single-phase apparatus is that of the New York, New Haven & Hartford Railroad, leading out of New York City. Practically all the railroad service between New York and Boston, as well as the New England states, is over the four tracks of this railroad. The trains pass into the Grand Central Station in New York City over the lines of the New York Central & Hudson River Railroad, which is electrically equipped with the third-rail system for operation by direct current at 650 volts. Selection of the system for the New Haven railroad was restricted by the necessity of operating the New Haven trains over the New York Central tracks; but the decision was in favor of the single-phase system, notwithstanding the limitation that the locomotives must operate successively both by single-phase current and direct current.

The trains of the New Haven system leaving the Grand Central Station pass over 12 miles of the tracks of the New York Central system, operating from the third rail by direct current. They then pass to the New Haven tracks at full speed, receiving alternating current at 11 000 volts from the overhead trolley wires which extend 21 miles to Stamford, a total distance of 33 miles from New York, this being the end of the initial installation of the single-phase system.

The power house is located near the Stamford end of the electrified section and contains four 11 000-volt turbo-generators having an aggregate capacity of over 16 000 kw. The current passes directly from the generators.

The overhead trolley system consists of a steel contact trolley wire suspended every 10 feet from a copper trolley wire, which in turn is sus-

*This is an appendix to the paper by Mr. Westinghouse on "The Electrification of Railways."

pended at intermediate points from two steel catenary cables by triangular-shaped hangers. These cables are supported upon insulators resting upon steel bridges spaced at distances of 300 ft. along the right of way.

As in general there are four tracks and in some cases more, the comparatively light steel bridges are made to span the right of way and to carry as many sets of the trolley conductors as there are tracks. Stronger bridges to which the catenary cables are anchored are located about every two miles. At certain points these anchor bridges are utilized for supporting the block signals and also to carry oil circuit breakers which permit the trolley wires to be sectionalized for service operation or in emergencies. Normally all the trolley wires and the supporting cables over all the tracks are connected together electrically and also to the source of supply at the power house.

There are 41 locomotives in regular operation, and also four motor cars with six trail cars operating on the multiple unit system in suburban service. The alternating current is taken from the overhead wire by a pantagraph which presses a shoe against the wire. The direct current on the New York Central zone is obtained from the third rail by means

TABLE I.—RECORD OF SINGLE-PHASE SERVICE

NEW YORK, NEW HAVEN & HARTFORD RAILROAD FOR 12 MONTHS

1909.	Total Miles Run	No. Locomotive Delays	Miles Run per Locomotive Delay	No of Power House Delays	No. of Line Delays
April	146 189	9	16 243	..	3
May	155 551	25	6 222	1	3
June	166 759	14	11 911	..	4
July	183 434	13	14 110	..	2
August	177 714	14	12 694	..	5
September	189 656	14	13 547	..	1
October	174 400	11	15 854	1	4
November	173 370	10	17 337	..	1
December	167 808	23	7 296	..	3
1910					
January	163 274	28	5 831	..	2
February	138 929	12	11 577	..	1
March	156 901	12	13 075	..	1

of ordinary sliding contact shoes. Both the pantagraph and the contact shoes are manipulated by compressed air.

For reasons of economy in operation the locomotives were built under the requirement that each should be capable of hauling a 200-ton train from New York to New Haven, making all station stops in accordance with the regular schedules, or an express train of 250 tons, and that the locomotives should be so arranged that two or more could be operated by a single engineer for the movement of heavier trains. The particular size selected permits about 75 percent of the trains to be operated by a single unit.

During the past year, the electric service has surpassed in efficiency all records previously obtained on this division with steam locomotives. The actual figures are given in Table I, which covers the movement of passenger trains over the 12 miles of third-rail operation and 21 miles of single-phase operation, for which 41 locomotives, that have been used from 22 to 33 months, were available. The early fears as to difficulties in commutation have been dispelled by the records of performance, as many of the motors have operated over 100 000 miles without turning or

even sandpapering the commutators, and the brushes show an average life of 40 000 to 45 000 miles.

The average number of miles run per locomotive delay during the year exceeds 12 000, equivalent to a dozen trips between New York and Chicago, or thirty-seven trips between London and Glasgow. The locomotive delays (many of which only slightly exceeded one minute duration) include not only those from electrical causes, but from mechanical defects as well, such as loose tires, burst airhose, hot journal boxes, frozen steam hose, etc. A comparatively large number of delays in December and January was due to the very severe weather and the unusual amount of snow and ice. These locomotives have been making regularly an average of about four and one-half trips of 33 miles per day, hauling trains 25 to 50 percent heavier, or even more in the case of express trains, than the locomotives were guaranteed to handle. Most of the locomotives have run about 100 000 miles, but there is seldom more than one (which is 2.5 percent of the whole number) out of service for repairs, a record said by the officials of the company to be much better than for the steam locomotives which were replaced. These officials also say that the cost of maintenance per mile and the number of miles run per electric locomotive are for more favorable than with steam locomotives, even with the present very short run of 33 miles. The cost of maintenance of the distribution system is relatively small compared with that of the low-voltage third-rail system. The delays due to the transmission lines and overhead construction, though few in number, include those brought about by extraordinary conditions, such as steam from switch engines and by wrong operation of switches.

The heaviest traffic on the New York division of the New Haven road, and the occasion on which delays would be most deplored, is on the day of the annual inter-collegiate football game at New Haven. The service on these days for 1908 and 1909 was as follows:

	1908	1909
Regular trains	128	126
Special trains	30	29
Total trains	158	155
Number of train delays	2	0
Total duration of delays	17 min.	

In considering the capability of the single-phase system for continuous performance, the record of the six single-phase locomotives in service at the St. Clair Tunnel of the Grand Trunk Railway is worthy of mention. These locomotives have now been running two years and have made about 70 000 miles each, averaging about 100 miles per day, or 25 trips of four miles. It has not been necessary to use a steam locomotive since the regular electric service was started (May 1908) and during the last 12 months the service has been responsible for but one train delay—of eight minutes.

SYSTEMS OF ELECTRIFICATION FOR RAILWAYS*

The salient features of the three systems of railway electrification are presented in a number of diagrams so arranged as to permit of a ready comparison between their essential characteristics, particularly in the circuits and apparatus which transmit the power from the power station to the locomotive. The perspective sketches, Figs. 1 to 4, show the commonly used types of apparatus and circuits in a simple and elementary way, as only a single generator and a single sub-station, containing but one group of units, are shown, and auxiliaries such as switchboard apparatus are altogether omitted.

*This is an appendix to the paper by Mr. Westinghouse on "The Electrification of Railways."

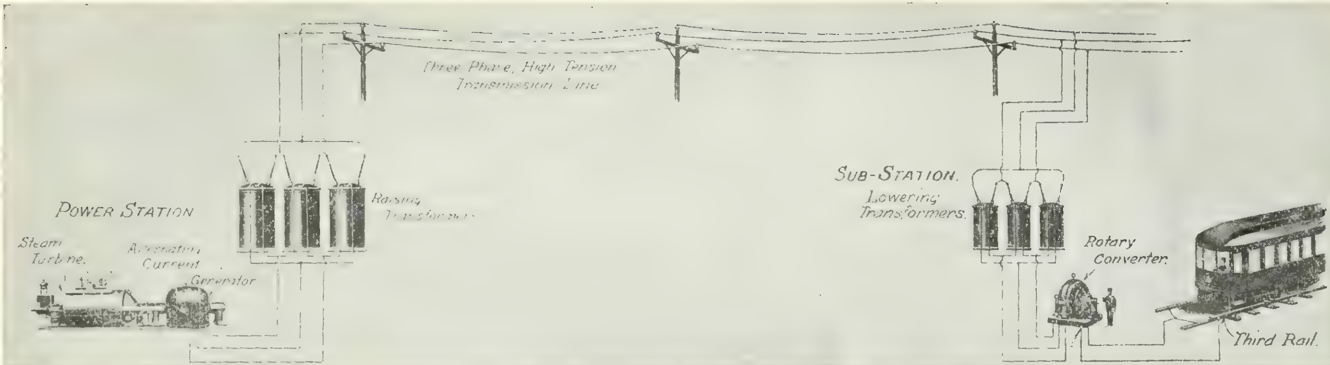

FIG. 1—DIRECT-CURRENT RAILWAY SYSTEM
Alternating-Current, High Tension Transmission, a Sub-station with Transformers for lowering the Pressure and Rotary Converters for Converting to Direct Current.

FIG. 2—THREE-PHASE RAILWAY SYSTEM
Alternating-Current, High Tension Transmission and Sub-stations for lowering the Pressure. Double Trolley Lines.

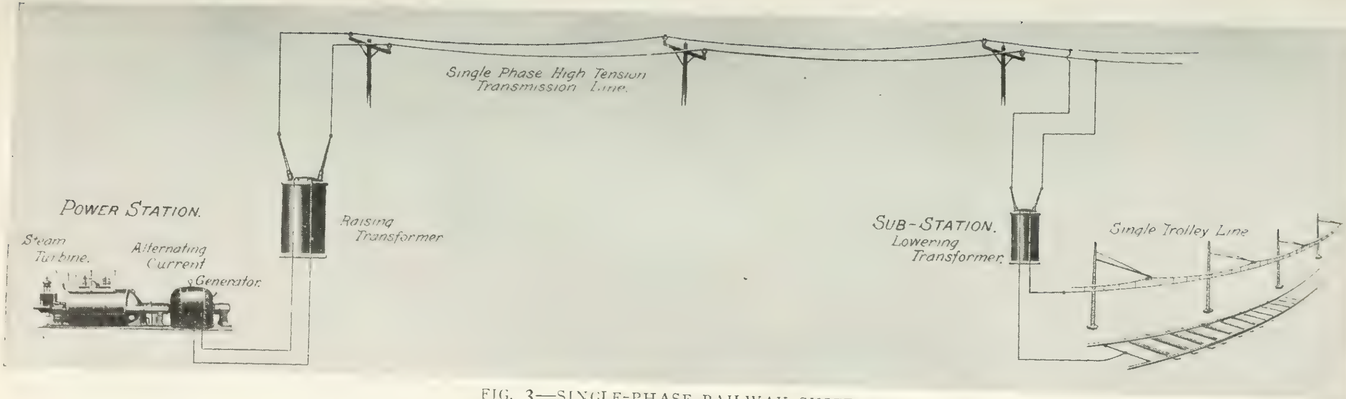

FIG. 3—SINGLE-PHASE RAILWAY SYSTEM

High Tension Transmission and Sub-stations for lowering the Pressure for Single Trolley Line.

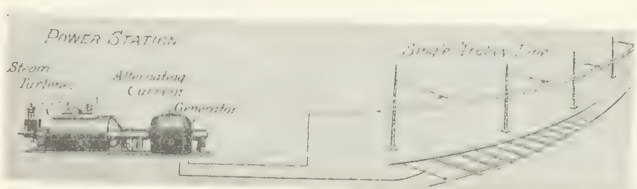

FIG. 4—SINGLE-PHASE RAILWAY WITHOUT TRANSMISSION SYSTEM

Generator Supplies Trolley Line Direct without Intervening Transmission System.

Fig. 1, showing the direct-current system, illustrates the alternating-current generator, the three raising transformers, the three-phase transmission circuit, the three sub-station lowering transformers, and the rotary converter which supplies direct current to the third-rail contact system.

Fig. 2, illustrating the three-phase system, is similar to Fig. 1 up to the point where the power passes the sub-station transformers. Power is then delivered directly to the contact system, consisting of two overhead trolley wires, shown suspended from supporting cables in accordance with the commonly used catenary construction.

Fig. 3, presenting the single-phase system, has a similarity to the preceding sketch of the three-phase system, Fig. 2, and may be derived from it by simplifying its several elements. Single transformers instead of groups of three are found in the power house and sub-station. The transmission has two wires instead of three and there is but one trolley wire instead of two.

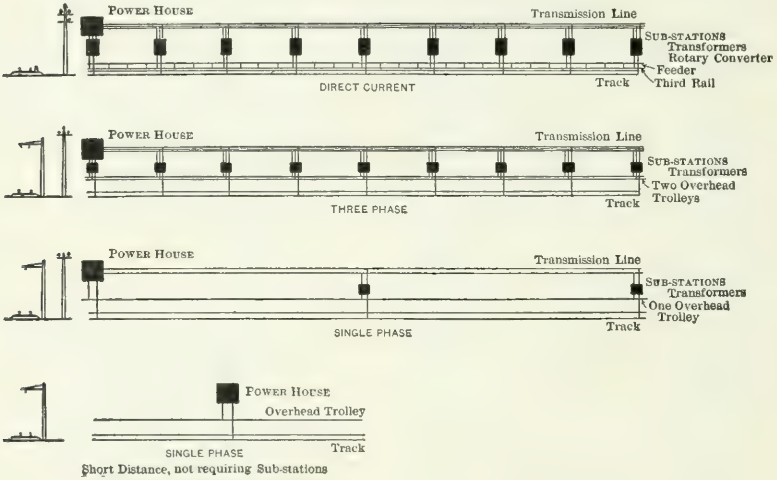

FIG. 5—ELECTRIC RAILWAY SYSTEMS—DIAGRAMS SHOWING TRANSMISSION CIRCUITS, SUB-STATIONS AND CONTACT CIRCUITS BETWEEN POWER HOUSE AND LOCOMOTIVES, CORRESPONDING TO SKETCHES IN FIGS. 1 TO 4

Fig. 4 shows the single-phase system where the distances are moderate and the generator can supply current directly to the trolley wire at 11 000 volts, thereby eliminating the high-tension transmission circuit and the sub-stations. This is the method employed in the single-phase installation on the New Haven system.

DIAGRAMS OF TRANSMISSION CIRCUITS AND SUB-STATIONS

Fig. 5 shows the arrangement of transmission lines and contact circuits and the relative number and location of sub-stations for each of the three systems. The direct-current sketch shows the three-phase transmission line running from the power house to the sub-stations, which contain step-down transformers and rotary converters for changing the high-potential alternating current to low-potential direct current. It also shows the third rail supplemented by an auxiliary conductor or feeder. The track serves for the return circuit.

In a certain typical case it was found that the sub-stations should be approximately eight miles apart for a pressure of 600 volts in the direct-current system. If direct current were used at a pressure of 1 200 volts, half of the sub-stations could be omitted.

The distances above mentioned are found to be proper for a particular case and the diagram is intended simply to show approximately the relative number of sub-stations required in the several systems. The actual distances in other cases may be more or less than those given. In the several systems employing a transmission line the distance may obviously be extended to include a greater number of sub-stations than are shown.

The three-phase sketch shows the three-phase transmission line and sub-stations containing transformers only, for reducing the high-potential alternating current to low-potential alternating current for use on the double overhead trolley system with track return. The sub-stations are spaced the same distance apart as those in the direct-current system. This arrangement of sub-stations is for 3300 volts on the trolley. With 6600 volts on the trolley, half of the sub-stations would be omitted.

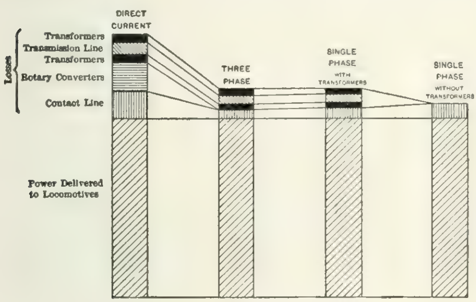

FIG. 6—SHOWING COMPARATIVE LOSSES BETWEEN POWER HOUSE AND LOCOMOTIVES

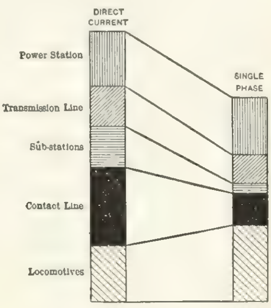

FIG. 7—COMPARATIVE FIRST COSTS IN A PARTICULAR CASE OF 100-MILE SERVICE

The larger single-phase sketch shows a single-phase transmission line running to sub-stations containing transformers only, to reduce the high potential alternating current of transmission to a suitable potential for use on the single overhead trolley with track return.

The smaller single-phase sketch shows a single-phase line which is not too long to prevent the entire system from being fed directly from the generators without the intervention of transmission line or transformers between the generators and the trolley circuit. This sketch shows the method employed on the New Haven system.

In thickly populated districts congested with traffic, the generating stations, of which there should be not less than two in order to minimize interruptions to traffic, should probably be located at junction points or places demanding the greatest power and at distances not exceeding thirty or forty miles. With such a disposition of power houses, the overhead trolley wires will usually be sufficient for the supply of current. In like manner, where the traffic is not so heavy, the power houses can be placed at greater distances, bearing in mind, however, that the increase in traffic may subsequently demand intermediate power houses or sub-stations. In cases where power stations are long distances apart, the single trolley wire should probably be supplemented by an additional circuit in order to guard against interruption due to defect in the trolley wire, and to give a sufficient supply of power for any contingency.

COMPARATIVE LOSSES

Fig. 6 shows the comparative losses between the generators and the locomotives for each of the three systems, based on a class of service where the input to the locomotives by the several systems is practically the same. As some kinds of service render one type of motor with its auxiliary apparatus and control more efficient, while under other conditions it may be less efficient, this variable element has been eliminated by assuming the same power delivered to each locomotive as a basis for a general comparison of the transmission losses.

The total height of each column in the diagram indicates the total power delivered by the power house in the system designated. The height of the long portion at the lower part of each column indicates the amount of power which reaches the locomotive.

The loss between power station and locomotive is represented by the upper shaded lines. The respective losses in raising transformers, transmission line lowering transformers, rotary converters and the contact line (comprising trolley or third rail with track return) are segregated. It will be noted that the large losses in the rotary converters appear only in the direct-current system. The larger single-phase column shows the losses where the distances are such that it is necessary

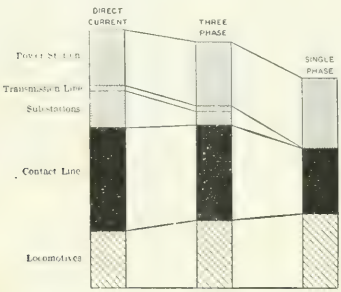

FIG. 8—COMPARATIVE FIRST COSTS IN THE DIFFERENT SYSTEMS FOR A SPECIAL CASE OF PUSHER SERVICE

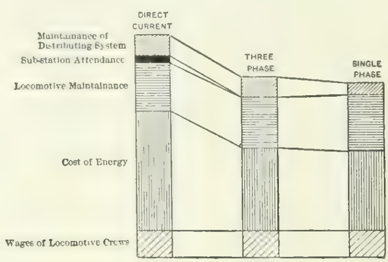

FIG. 9—COMPARATIVE OPERATING COSTS IN THE DIFFERENT SYSTEMS IN A SPECIAL CASE OF PUSHER SERVICE

to use a transmission line and transformers. The smaller single-phase column represents the trolley wires connected to the generators without any intervening transmission line or transformers. The loss of power between power house and locomotive is relatively small as compared with that in any of the other systems. This is the condition on the New York, New Haven & Hartford Railroad, where the power house is distant nearly 20 miles from one end of the line.

COMPARATIVE FIRST COSTS

Fig. 7 shows the comparative estimates prepared a few months ago of first cost in a particular case for electrification by the direct-current system and by the single-phase system. In the preparation of these estimates the three-phase system was not called for and as no estimate covering it has been prepared, it is not included in the present comparison. The estimates cover a single track line 100 miles long involving both freight and passenger traffic in both through and local service and include twenty locomotives.

The costs for power stations include only the machinery and building and do not include cost of hydraulic development. It will be noted that the considerably less cost of the single-phase system in this case is due largely to the lower cost of contact line and sub-stations.

Fig. 8 shows the comparative estimates of first cost for the three systems for pusher service on mountain grades in a particular case involving the use of twelve locomotives. The total length of line is 32 miles, part of which is single track, part double track and part three tracks. In addition to the main line there is a large yard to be electrified, there being a total of 90 miles of single track. The location of the power station was fixed by non-electrical considerations. The distances were such that sub-stations were required when either direct current or three-phase current was assumed, but the entire system could be fed direct from the generators if single-phase current were used. It will be noted that in this case the omission of sub-stations and transmission effects a very considerable saving in favor of single-phase a well as the usual large saving in cost of contact line effected by the use of this system. The cost of the part of the system between the power house and the locomotives in the direct-current system is nearly equal to the cost of both power house and locomotives. On the other hand, the cost of the single-phase contact line, the only intervening element between the power house and the locomotives, has less than one-half of the cost of the direct-current transmission and contact system.

COMPARATIVE OPERATING COSTS

Fig. 9 shows comparative operating costs for the three systems for the pusher service outlined in the preceding diagram of first costs. It should be noted that these costs do not include fixed charges. If fixed charges were included the difference in operating costs in favor of the single-phase system would be much more marked. In connection with this diagram it should be noted that sub-station attendance is required for the direct-current system only. The reason for the three-phase and single-phase systems being so nearly on a par is that this case is an ideal one for the application of the three-phase system since it involves constant-speed operation under constant-load conditions. It is notable, however, that even under these conditions the single-phase system shows somewhat lower operating costs than the three-phase system.

The high operating cost with the direct-current system is seen to be largely due to the greater amount of power required for operation by this system on account of the large losses which occur between the power house and the locomotive in this system.

DEVELOPMENT OF THE LEBLANC CONDENSER IN AMERICA

R. N. EHRHART

TWO years ago the Leblanc condenser was comparatively unknown in America. To-day there is the equivalent of over 500 000 horse-power represented in the sales of this type of condenser. The original design of the Leblanc* condenser was only adaptable for motor drive, as in England and continental Europe, for various reasons, nearly all power house auxiliaries are motor driven; while in America the use of motor-driven auxiliaries is comparatively rare. During the inception of their condenser business, The Westinghouse Machine Company early realized the desirability of adapting their apparatus to steam drive. There were two possibilities, either reciprocating engines or steam turbines. The first named seemed to be the easiest method on account of the high state of development of the steam engine and the well established facts pertaining to moderate speed centrifugal pumps. The second method, that is, the use of turbine drive, while possessing many great advantages, presented the difficulty of successfully reconciling the speeds of turbines and pumps. Nevertheless, the advantage in favor of steam turbine drive was so evident that the problem of proportioning both turbine and pumps, so that each would satisfy the requirements imposed by the other, was vigorously investigated. After exhaustive experiments a steam turbine driven Leblanc condenser was developed which combines efficiency and simplicity in a striking manner, reversing the usual process of improving efficiency by making a more efficient piece of apparatus by simplifying rather than adding complications.

The steam turbine developed for this class of work is of particular interest on account of its relatively moderate speed. In the large Leblanc condensers the turbines develop 200 horse-power and operate at 600 r.p.m., and have economies comparable with those of simple slide-valve engines.

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*It may be of interest to note that the original inventor of this type of condenser is Maurice LeBlanc, the French scientist and electrical engineer. He has taken out numerous patents for electrical devices. One of the most familiar is that of the amortisseur or the well-known copper damper which is so usefully applied to alternators and rotary converters to prevent "hunting." Another is the adjustable resistance in the secondary circuit of an induction motor, by which the speed may be controlled.

The simplicity of the condenser is well shown by Figs. 1, 2, 3 and 4. All parts, that is, the complete outfit, are shown in each illustration except Fig. 3. In the sectional view, Fig. 2, it may be seen that the whole apparatus is self-contained. There are no accessories to be scattered around the power house. The moving parts consist of only one shaft with two rotating wheels, the rotors of the centrifugal and air pumps. The condenser section itself does not involve anything particularly novel as compared with other well-known types of jet condensers. In combination with the Leblanc air pump, however, it presents a distinct epoch in the state of the art. A detailed description of the air pump will, therefore, give a definite idea of the salient features of the Leblanc condenser.

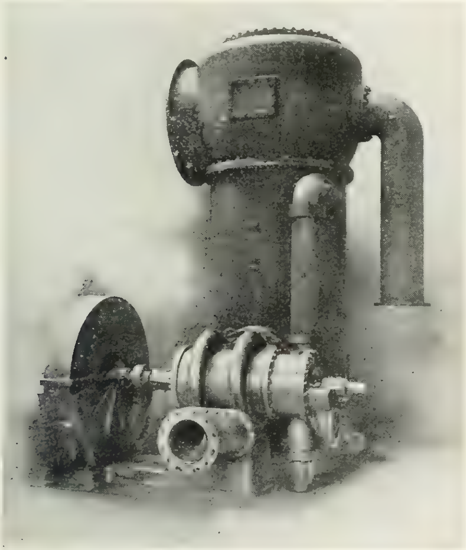

FIG. 1—STEAM TURBINE, DRIVEN LEBLANC CONDENSER

THE LEBLANC AIR PUMP

That a jet of water can be used to compress air was known centuries ago. In fact, the early inhabitants of Spain, when struggling against the Roman conquest, are known to have constructed rude smelters in which falling water in specially shaped tuyeres compressed sufficient air to enable them to successfully smelt metal for their domestic and warlike uses. During the past ten years efforts have been made to utilize a water jet to remove air from the condensers and compress and eject it against atmospheric pressure. The Westinghouse Machine Company made extensive experiments with water jets for this purpose, the results of which may be stated as follows:—

With the most efficient form of compression jet known today, one cubic foot of water must be passed by jet to entrain 1.5 cubic feet of air. It is necessary that the water be at a pressure or from 20 to 30 pounds per square inch to accomplish this. It is, therefore, evident that such a device would be extravagant in

the use of power if applied to condensers as a substitute for the reciprocating air pump. Condensers have actually been constructed in this way, and, while eminently successful as far as the pure problem of condensation is concerned, they are so extravagant in power requirements that they are essentially uncommercial.

While the Leblanc pump uses water moving at high velocity as a means for extracting air from the condenser, the actual process is entirely different from that where the pressure created jet is used. In the pressure jet, friction between air and water is the only factor at work to make the water extract air from the condenser. With the Leblanc pump from 5 to 7.5 volumes of air can be abstracted per volume of water, or, in other words, the same duty can be obtained with the Leblanc pump with one-fifth the power consumption of the pure jet pump as applied to a condenser.

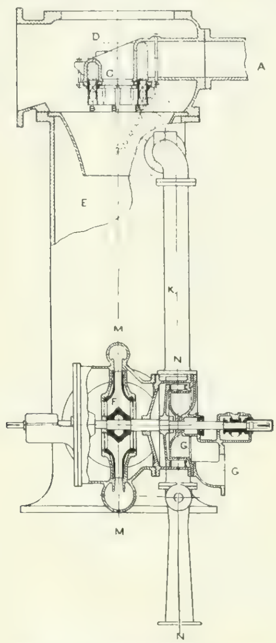

FIG. 2—SECTIONAL VIEW, LEBLANC CONDENSER

As stated before, the jet relies on friction for entrainment. In the Leblanc pump the water is mechanically divided into successive layers which entrain large volumes of air between them. These layers of water can be truly regarded as successive water pistons, each driving before it a charge of air.

A section of the air pump is shown in Fig. 3. Assuming that a vacuum has been established in the condenser, water will flow from the chamber *A* (which is connected to the source of injection) into the turbine wheel *B*, which is running in a vacuum. This wheel literally pares off thin layers of water, which are projected downwards through the diffuser *C*, and the interstices between these layers are filled with air. The layers are formed with great rapidity since every blade generates a layer, and it follows that such a pump inherently has great volumetric capacity for pumping air.

A pump of this type also possesses inherent qualities which make it particularly suitable for condenser service. The air to be handled is very rare or attenuated, consequently a given weight occupies a great volume. The handling of air from a condenser ne-

cessitates relatively large pipes with a minimum amount of restrictions, since any restrictions will simply mean a loss of vacuum. The reciprocating air pump, with its devious ports, valves, etc., cannot help but offer a very material resistance to the flow of air. The Leblanc air pump is a self-contained part of the condenser. The flow or air is short and direct to the point of entrainment, absolutely free from the restrictive losses found in the reciprocating pump.

The rarer the air to be handled the lower is the efficiency of the reciprocating pump, since the restrictive losses become relatively greater as the rarity of the air increases. This is evident, since the velocity through the ports, etc., must increase as the volume of air

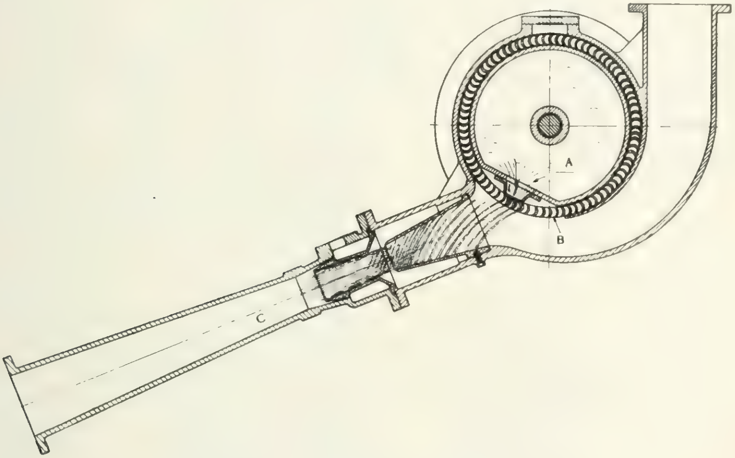

FIG. 3—CROSS-SECTION OF LEBLANC CONDENSER AIR PUMP, SHOWING PRINCIPLE OF OPERATION

A—Chamber leading from source of injection.
B—Turbine wheel which runs in a vacuum.
C—Diffuser which receives the layers of water projected by the blades *B* and the air which it entrains.

is increased, due to greater rarification. With the Leblanc pump, however, the volumetric efficiency actually increases as the air becomes more attenuated. This is clear since the layers of water drive cut the entrained slugs of air by impact. If the air is attenuated its inertia resistance is less, hence the rarer the air the greater the volumetric efficiency.

Actual experience has demonstrated that for high vacuum work the Leblanc pump is superior to the reciprocating pump and for vacuums less than 26 inches the reciprocating pump seems to have the advantage.

THE TRUE MEASURE OF CONDENSER EFFICIENCY

The fundamental theorem of the operation of a condenser is known as Dalton's law, and may be briefly stated at follows as applying to condensers:—

The total pressure of a mixture of vapor and gas is equal to the sum of the individual pressures exerted by the vapor and gas.

The problem in the condenser is to reduce the pressure of the gas (air) to the lowest possible value so that the pressure in the condenser will be substantially that of the vapor. It is, of course, impossible to eliminate the vapor pressure since the condenser is

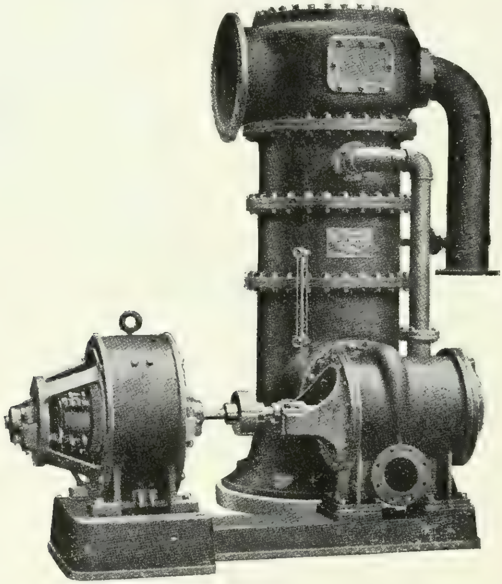

FIG. 4—MOTOR-DRIVEN LEBLANC CONDENSER

by name and nature a receiver of all the vapor that can be put into it. However, it is possible to keep the vapor pressure down by circulating enough water through the condenser to cool the vapor to a certain definite temperature. It, therefore, follows that the vapor pressure in the condenser will be that corresponding to the temperature of the ultimate mixture of condensed steam and water.

For example, if steam and water be mixed to attain a final temperature of 101 degrees F., vapor at a pressure of one pound absolute will be given off by this mixture; or, in other words, water at certain temperatures gives up vapor at definite pressures. This can be found tabulated in any steam table.

It follows that the lowest possible pressure that can be maintained in the body of the condenser is that due to vapor pressure and this only when there is an air pump on the condenser which can pump out the air so that its pressure is negligible. It is, therefore, apparent that in a perfect condenser the temperature of the discharged mixture of water and steam will bear a definite relation to the absolute pressure in the condenser; that is, the pressure in the condenser will be that of the vapor at the discharge temperature.

TABLE I—DATA OBTAINED FROM CONDENSERS IN ACTUAL COMMERCIAL OPERATION.

Installation	Temperatnres Injec'n	Disc'ge	Vacu'm ref. to 30" bar	% Ideal Vacu'm	Remarks
Southwestern Portland Cement Co., El Paso, Texas	43 43	61 60.50	29.35 29.35	99.7 99.7	Load varied from 400 to 450 kw.
Potlatch Lumber Co., Potlatch, Idaho	34 34	70 76	29.0 28.9	99.1 99.3	Load on low pressure turbine varied from 300 to 360 kw.
Alpha Portland Cement Co., Manheim, W. Va	73	104	27.9	100	Load 800 kw.
Western Ohio R. R. Co., St. Marys, Ohio	46	73	28.9	99.1	Load on low pressure turbine 1150 kw.

If the discharge temperature is 101, the pressure in the perfect condenser should be one pound absolute or 28 inches vacuum (approximately), or if the temperature were 78 degrees, the pressure should be one-half pound absolute or 29 inches vacuum (approximately).

From the foregoing it may be seen that for any given ultimate temperature of the mixture in the condenser, a certain definite vacuum can be attained. The data from commercial tests given in Table I show the percentage of theoretically attainable vacuum actually reached. These high efficiencies are only possible by the use of the very effctive type of air pump which keeps the air pressure component in the condenser down to a negligible figure.

SCIENCE AND INDUSTRY*

L. H. BAEKELAND

NOWHERE have the changes of this century been so accentuated as in our industrial enterprises. We know, furthermore, that the industries in which the developments have been most staggering are exactly those which have utilized scientific knowledge to the largest extent. The modern engineer, in intellectual partnership with the scientist, is asserting the possibilities of our race; instead of cowering in wonder or fear before the forces of nature, instead of perceiving in them merely an inspiration for literary or artistic effort, he learns the laws of nature and sets himself to the task of applying his knowledge for the benefit of the whole race.

I dare say that the last hundred years under the influence of the modern engineer and the scientist have done more for the betterment of the race than all the art, all the civilizing efforts of the so-called classical literature of past ages, for which some respectable people want us to have such exaggerated reverence.

It has been asserted so often that science and industry cater only to our material welfare, and have little in common with culture, refinement or moral development, that I feel compelled to put special emphasis on this side of the question and to insist on the enormity of the error. On the contrary, the development of our industries, of our material prosperity, as well as the study and application of science, are the surest and most immediate forerunners of higher civic ideals, of an improved society, of a better race.

A clean, well nourished and well housed individual, who can enjoy the comforts and advantages of modern surroundings, and leads an active, intelligent, productive, self-supporting and self-respecting life, is certainly more of a man and a credit to his race than were some ancient saints who lived from alms, or who, for the further edification of their followers, vowed never to change their clothes, nor wash nor shave nor comb themselves; he is more of a blessing to his fellow-man than the useless drone who lives on the work of others and gives nothing in return but arrogant presumption based on fortune, rank or title inherited from his father.

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*Extracts from the presidential address before the annual meeting of the American Electrochemical Society, Pittsburg, May, 1910.

If this be the age of rational industrialism, of applied science, how then is it that in some industries quality is going down, while prices are soaring upwards?

Here again, it is a noteworthy fact that just such commodities as are produced by so-called scientific industries are sold cheaper and are of better quality than ever before, and this cheapening of price or bettering in quality is almost proportionate to the amount of scientific knowledge involved in their production. Take, for instance, the chemical and the electrical industries, both based almost exclusively on well developed scientific data. In both these groups of industries the chemist or the physicist has had full sway and the engineer has embodied their work in a practical form. Free and rational competition based on intellectual superiority has been their paramount factor of development. Competition based on artificial privileges, like labor unions and tariff legislation, have played only a secondary rôle. Acids, alkalies, salts, solvents, dyes and, in general, almost all chemicals, are incomparably cheaper and of better quality than they were in the good olden times.

In some cases, the changes are remarkable. For instance, a ton of sulphuric acid sells now at the same price as two pounds of the same article were sold about a hundred and fifty years ago, and it is better acid. A similar cheapening can be found in many other chemicals although their demand has immensely increased. Without going to extreme cases, we can state that there has been a steady improvement in most chemical manufacturing processes and that the public at large has had the benefit thereof. The same can be said of the electrical industry.

All this does not take away the fact that although some industries suffer from brutal ignorance, others have sometimes been handicapped by a too one-sided scientific organization; I know of some instances, especially in Germany, where very respectable enterprises have not utilized their available opportunities to the proper extent, because their scientific managers lacked good business sense. The most learned man without common sense or practical abilities can accomplish little except disappointments. Here is where the keen business man, with a practical turn of mind, with directness of purpose and good judgment, will every time show his advantages.

An over-specialized man, whether he be a biologist, a physicist, a chemist or an engineer, may lack the broadness of conception and action which characterizes true great men of many-sided development.

Then again, quite frequently the real field of usefulness of scientifically trained men is much misunderstood. For instance, it is a common mistake to imagine that the main work of the chemist is confined to performing chemical analyses. This conception is about as absurd as to think that the essential work of the merchant is bookkeeping.

In the development of some of our industries, nothing has played such an important rôle as scientific research work. Not so long ago, research work was only carried out in the laboratories of universities or in those of a few highly developed chemical or electrical companies; nowadays we find many intelligently conducted enterprises devoting a considerable annual outlay for systematic research work, where the resources of the chemist, the physicist and the biologist are used to good purpose.

Unfortunately, the scope and method of scientific research is difficult for the uninitiated to understand. Some manufacturers, totally unaware of the requirements involved in this work, in a half-skeptical way, grudgingly conclude to organize a research department, sometimes as a last resort, to help them through some difficulties. Frequently they engage a young man with little experience, who, outside of what he studied in the technical school or at the university, has everything to learn, and who, besides that, is usually entrusted at the very start with the most puzzling problems.

A research department is a very difficult thing to organize and to run. It is not enough to provide a building and the necessary appliances; it is not enough to provide typewriters, card-indexing systems, an office force, and all the red tape connected with it; it is not sufficient to engage one or more well-behaved university or college graduates with the necessary helpers, and to let them work under an orderly, business-like manager. You might as well try to produce masterly paintings by installing an office management and a well-organized paint and brush department, and a library containing all that has been written on the art of painting, next to a splendidly equipped studio, and then leave out the real artist who will do the painting. The most important, the almost exclusive factor in a successful research laboratory as the research chemist himself. He should be a man who has a soul alive with his subject, enthusiastically imbued with his opportunities, and qualified for his task not only by scientific training but especially by a natural gift

of discrimination between what is most important in a problem and what is secondary to it.

Then if you find the man who has all the true qualifications, you may still paralyze his action by too much red tape, too much interference in his work. A good research chemist will do more and better work with pots and pans from the "ten-cent store" in a shed or in a barn, where he is his own master, than in a splendidly equipped laboratory where he gets irritated and interfered with by others who do not understand him.

Even if you have the best qualified research chemists, do not expect immediate results. Do not forget that problems, apparently most simple, require considerable time before they are thoroughly studied.

Research is what gives a young man of strong individuality a chance to compete with those big industrial consolidations, the trusts, who like elephants, look more imposing by their size than by their agility or perfection, and who, as that pachyderm, have many vulnerable spots, and are just as much handicapped by their lack of flexibility and by their ponderosity. Some steel manufacturers may be unable to think about anything but tonnage, and yet the work of some chemists has already indicated that the quality of the steel of the future, or of its alloys, may be improved to such a degree that probably the average steel of to-day will look to our children as brittle and imperfect as pig iron appears to us. Neither should we lose sight of the fact that even to the most exclusive mechanical enterprises there is a chemical side, although the importance of the latter may not be apparent to the man who is not a chemist.

Let me give also a warning to such manufacturers who try to secure only by uncompromising secrecy, the money-making end of their industries. If the chemists had been holding their results from each other, we should be still in the dark ages of the alchemist. No secrecy, however jealously carried out, can outweigh enlightened research work, protected by wise legislation. If our patent laws do not protect enough, then our prime duty becomes to change them until they answer their purpose as defined by the Constitution.

INVESTIGATING MANUFACTURING OPERATIONS WITH GRAPHIC METERS

C. W. DRAKE

IN order to obtain a concrete idea of the power required to operate electrically driven machinery for any considerable length of time by the use of ordinary portable meters it has been customary to take readings at frequent intervals and then plot these readings in curve form. In addition to this being a very irksome task, the curves are not accurate between the points plotted and even these points are subject to the personal equation of the tester. The graphic meters which have recently been brought to a high state of perfection not only relieve the operator of a very tiresome task but produce a continuous record in curve form, the accuracy of which is far beyond anything that can be expected from readings of portable meters.

Such a testing outfit, consisting of a polyphase graphic meter with the necessary instrument transformers as used in a factory, is shown in Fig. 1. When desired indicating meters may also be used. It is thus possible to arrange the dampers on a graphic meter of this kind so as to give a good average of the power required while the instantaneous values of current, voltage and wattage may be determined from the indicating meters.

To be satisfactory for all classes of service, a graphic meter should be capable of adjustment both as to paper and pen speeds. For large power house work a rather slow paper speed and a well damped pen are usually desired since only an average curve is wanted. For the testing of individual motors where is it desired to obtain a record of the starting current at different controller notches, or where the load is exceedingly variable the paper speed should be higher and the pen should be quite sensitive. The standard clocks used in the meters of the type illustrated give speeds of two, four and eight inches per hour, but special gears may be used which will give a speed of twenty-four inches an hour. The sensitiveness of the pen may be varied so that the time it takes to travel across the entire scale will vary from one to thirty seconds. This variation is obtained by adjusting the dash pots or by filling them with different oils. The accuracy of the meter is always the same, however, since the meter works on the relay principle and the only power taken from the meter transformers is that necessary to operate the light meter elements.

Any meter is liable to a change of calibration when shipped by express or otherwise subjected to rough usage, but since this type

of graphic meter* works on the Kelvin balance principle, the calibration may be checked up and corrected in a very short time by means of a self-calibrating weight which is sent with each meter. This makes it unnecessary to check the readings with a standard meter. In fact there are several cases on record in which a graphic meter has been used to check up portable meters.

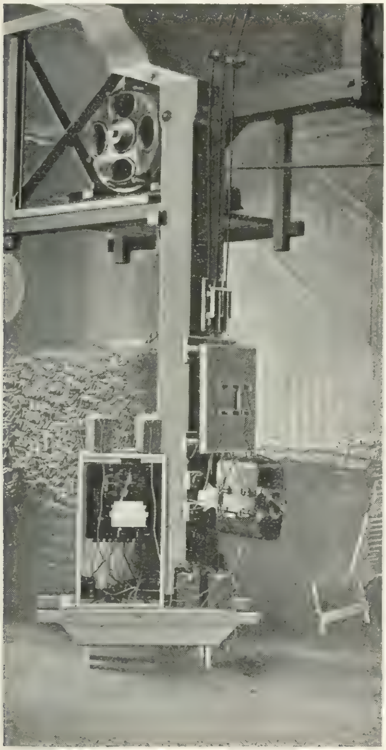

FIG. 1—POLYPHASE GRAPHIC WATTMETER

Assembled with instrument transformers for a shop test.

The power charges for motor loads are sometimes based on the connected load plus a kilowatt-hour charge, and sometimes simply on the meter readings. The minimum rate is proportioned in various ways, sometimes on the horse-power connected, sometimes on the maximum demand, or, perhaps, on a combination of these two. But regardless of the rate, the companies contemplating the installation of motor drive generally want to know approximately what their power demand will be before they install the electrical equipment. The first step is to figure the motor capacity required for the various machines from available data with due consideration to local conditions of operation. The average and maximum power that the motors will take can be estimated only after a very careful examination of the load and time factors of each machine, unless data on other similar plants is available.

A knowledge of the load factors obtained in various industries, together with the maximum demand and average working conditions, is of great value not only to central stations but also to consulting engineers and others who have occasion to estimate upon

*For description of this type of meter see JOURNAL for May, 1906, p. 297.

the electrical operation of industrial plants. The graphic recording meter is the only instrument which will show and record how much power has been used, when it was used, and the amount and duration of the maximum demand. The accompanying curves are shown to give a general idea of what can be done along this line.

EXAMPLE I—WAGON WORKS

A portion of a total load curve of a small wagon works having 16 squirrel cage induction motors installed, aggregating 32.5 horsepower, is shown in Fig. 2. The peaks, or high places, on this curve are caused by starting the motors, which, on account of their small size, are started directly from the line without the use of autostarters. One of the most conspicuous lines of the curve is the forge blower load, which is very constant and approximately one kilowatt. While the motor connected to the blower in this installa-

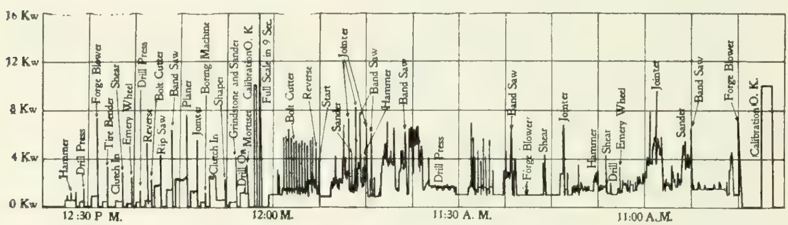

FIG. 2—WAGON WORKS POWER LOAD
Showing total load on 16 motors aggregating 32.5 hp.

tion had a capacity of only three horse-power, it consumed 55 percent of the total power required by the plant owing to the fact that it operated continuously. During the ten-hour day during which the test was made, 18.2 kilowatt-hours were consumed, corresponding to a plant load factor of about six percent, based on the connected load. The power taken by the motor driving the bolt cutter may be seen on the curve at 11:55, the average load being about one-half kilowatt, while the peaks caused by reversing the motor on full voltage reach five or six kilowatts. No tight and loose pulleys or clutches are used, the motor being reversed quickly when the die reaches the correct distance on the bolt. This form of drive has worked very satisfactorily. At the left end of the curve may be seen a comparison of the starting conditions and friction loads of the various machines running singly. This test was made during the noon hour with the pen on the recording meter adjusted so that it took nine seconds to travel across the sheet. A change of one kilowatt was therefore covered in one-half second.

Had line shaft drive been used in the above plant, about nine or ten kilowatts would have been required to supply the friction losses alone. As the plant showed an hourly average consumption of about two kilowatts, this means that the friction loss would have represented about 80 percent of the total power consumed. It is on account of this extremely low load factor, which is obtained in wagon works, planing mills, sash and door factories, etc., that the individual motor drive shows such great economy in factories of this class.

EXAMPLE II—SAW MILL

The curves shown in Fig. 3 were obtained in a saw mill, the

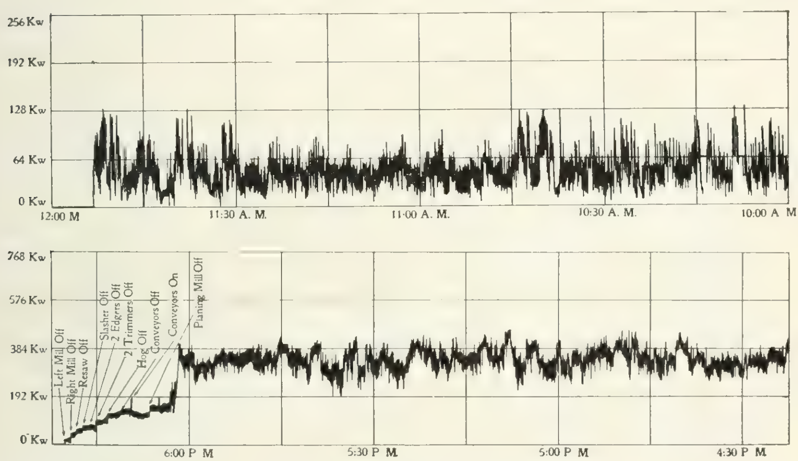

FIG. 3—LUMBER MILL POWER LOAD

The upper curve shows the load on a 150 hp, wound secondary motor driving an 8 ft. band mill. The lower curve shows the total load on the mill.

lower curve being taken from the total load curve of the mill, while the upper curve shows the nature of the load on a 150 horse-power induction motor, belted to an eight-foot band mill. The feed for the carriage of this mill is of the usual steam shot-gun type, and consequently is entirely under the control of the operator, varying, as a rule, from 150 to 250 feet per minute. The lower wheel of a band mill of this type is built in the form of a fly-wheel, which is used to give the necessary tension on the saw and also to equalize the loads on the driving mechanism. Since the wheel on a saw of these dimensions weighs between three and four tons and revolves at approximately 350 r.p.m., it has always been considered that the power demand on a motor driving the saw would be very steady.

The curve shows, however, that the power varied from 30 to 150 horse-power within two or three seconds, indicating that the fly-wheel gave up but little of its energy. This brings out the point that a fly-wheel will not deliver energy unless it drops in speed, and when driven by a motor having constant speed characteristics, very little of the stored energy in the fly-wheel can be utilized. The simple steam engines formerly used for driving saw mills had very poor regulation and, consequently, allowed the fly-wheels to take the larger part of the peaks. The motor in question, being of the wound rotor type, could easily be arranged to give six or seven percent slip instead of the three or four percent actually obtained. This would materially decrease the demand on the system, and as the curves show that the 150 horse-power point is seldom reached

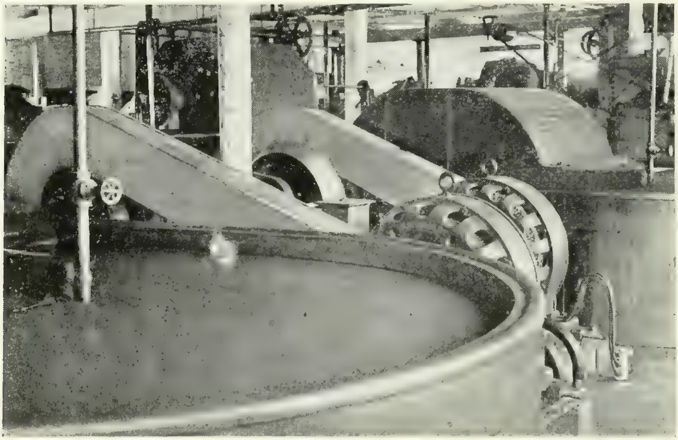

FIG. 4—50 HORSE-POWER MOTORS DRIVING RAG BEATERS

under present circumstances, a smaller motor would be entirely suitable for the work done while this curve was being taken.

There are two types of induction motors available for this class of service, the wound rotor and the squirrel cage. The former type has many advantages, since the mill may be brought to full speed with a smaller demand on the system and any desired slip may be obtained by inserting suitable resistance in the secondary circuit. The squirrel cage motor is simpler in construction and cheaper and may be designed for a high starting torque which will readily bring the mill to full speed. When once constructed, however, it is impossible to vary or modify its regulation as can be done in the case of a wound rotor machine.

The lower curve is of interest in comparison with the total load on the wagon works, Fig. 2. The comparatively high load factor obtained here is due to the practically continuous operation of the various machines throughout the mill. Low points occur now and then when a band mill is shut down to change saws or when some difficulty arises in the mill, but otherwise the entire mill works at a very high load factor. After six P.M. the record was continued in order to find the friction load of the individual machines.

EXAMPLE III—PAPER MILL

In the manufacture of paper of nearly any grade or quality, beaters play a very important part in the reduction of the fiber

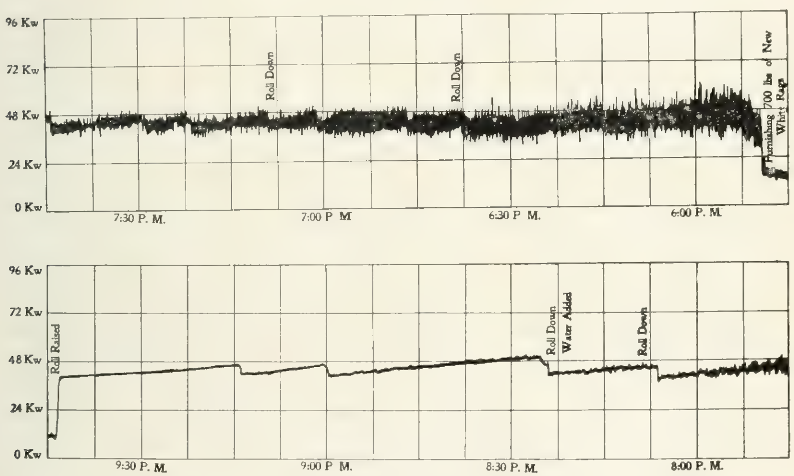

FIG. 5—LOAD CURVE ON 50 HORSE-POWER MOTOR DRIVING A RAG BEATER IN A PAPER MILL

The curve is continued from the upper half to the lower half.

to the desired length. The horse-power required by any beater depends on many variables, principal among these being the diameter, length and speed of the roll, the kind of stock and the method of working. Since the quality of paper depends to a very great extent upon the condition of the pulp when it leaves the beater, considerable care and attention is necessary during the process of beating. It is also of importance to beat the stock as fast as possible in order to obtain the maximum production and reduce the number of beaters required for a paper machine. With individual motor drive, it has been found that a graphic meter with each motor af-

fords great help to the beater operators in maintaining a maximum production and a uniform product.

Two 50 horse-power induction motors of the wound rotor type driving 1 200 pound rag beaters are shown in Fig. 4, and the curve, Fig. 5, shows a portion of a test on one of these motors. The stock used consists of new rags from shirt factories and is used in the manufacture of a special black paper for photographic purposes. These rags are very tough. The first part of the curve (the upper section) shows the great variation in power when the fiber is long, and, later on, shows how the load becomes more steady as the fiber grows shorter. The saw-tooth appearance of the curve is due to the fact that the power gradually decreases as the fiber becomes shorter, but rises again each time the roll is lowered. By frequently lowering the beater roll, a nearly constant load can be

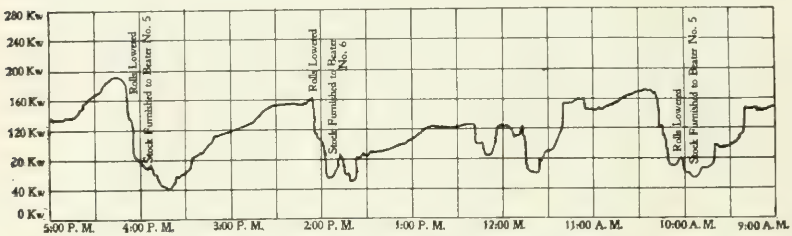

FIG. 6—LOAD CURVE ON 175 HORSE-POWER MOTOR DRIVING TWO RAG BEATERS.

maintained on the motor, with a consequent maximum production and uniformity of product at all times. Without the aid of a meter, the operators are forced to depend upon the sound of the machine for the amount of power it is taking, although the quality of the stock is determined by feeling it. A complete cycle of operation for a beater on this class of work takes from 15 to 18 hours, so that, without the use of meters, the product is subject to the personal equation of at least two men.

Of interest in comparison with the above is a curve shown in Fig. 6 which is taken from a graphic meter permantly installed in connection with a 175 horse-power induction motor driving two beaters. These beaters have the same size of roll as the one referred to above, but run at 150 instead of 120 r.p.m., and are used on old rags for the manufacture of felt paper. The low points on this curve show very clearly when a beater was emptied. The meter in this case is used principally as a check upon the time that the stock is in each beater and also as a check on the maximum de-

mand taken by the motor. The curve shows that the load is not maintained steady as in the former case, but that, after the roll is once set, it is left in that position for a considerable length of time.

By a careful examination of the working conditions in such a plant with the aid of a graphic meter and by proper instruction of the operators the load factor on the motors can be materially improved. This should result in a much greater output and a lower cost per ton of product.

The curves shown have been taken during the course of routine tests, under actual operating conditions of the various installations tested. In some cases it has been found advisable to connect a recording meter permanently in the circuit. The meter records form a valuable and permanent indication to the workman of the exact operating conditions of his machine and of the material on which he is working. In addition they furnish a continual check on the work, which enables the manager to see at a glance just how each machine has been operating during the day.

In most cases, however, the recording meter is installed in a motor circuit for a few hours only. By such a test, as shown by the curves, the proper size of motor to furnish power for a given machine can readily be determined. But more important still, the complete cycle of operations can be studied in detail and carefully analyzed. Such an analysis will frequently show a failure to attain maximum output and indicate where improvement may be made by some slight change in procedure.

As a means of careful and ready analysis; as a constant check on men and machines; as a means of equalizing the plant load, or of decreasing the rate of charge for power by decreasing maximum demands, and as a means of indirectly checking the delays caused by surrounding conditions which might otherwise remain unnoticed, the graphic recording meter is becoming invaluable both to the shop manager and to the central station solicitor.

SUPER-SPECIALIZATION*

PAUL LÜPKE

IN his address before the American Institute of Electrical Engineers, President Henry Gordon Stott made this statement:—

"This increased efficiency (due to specialization) will cease if the engineer becomes so highly specialized as to ignore the necessity of keeping in touch with the entire sphere covered by his company, as the evolution of each branch must be synchronized with that of all."

A somewhat similar statement made by President Butler, of Columbia, in reference to good citizenship, may be paraphrased without doing it great violence thus:—

"While it is indisputably right that every employee should do his very best in his department, it is nevertheless a plain fact that just as soon as any employee puts the interest of the department to which he belongs above the interests of the company as a whole he makes it impossible for himself to be a good employee."

It is not specialization in itself that is harmful, it is super-specialization to the exclusion of all general consideration. If we keep our backs bent forever in our own narrow furrow we will lose our sense of direction and run the risk of being brought up sharply against a dead end. Now and then we must straighten up, look over the walls we have thrown up around us, and take a calm and considerate general survey. Let me be specific to make myself clear. If I should ask a question concerning some intricate, technical, commercial or accounting problem, who doubts but what a highly trained specialist of one or the other departments would be ready, on the instant, with a satisfactory answer; and yet, on the other hand, suppose I asked point-blank, "What are the main considerations that govern your conduct in the actual performance of your duties as an officer or employee of a public utility company?" would you be ready to answer without hesitation? And if I suggested at random a round half-dozen such considerations as safety of the public, safety of fellow employees, adequate service, fair return to the investors, equitable treatment of consumers, just remun-

*Condensed from a paper read by the author at the 33rd convention of the National Electric Light Association, held at St. Louis, May 23-27, 1910.

eration of employees, would you have to hem and haw and think awhile if I asked you to place them in correct order of precedence and to give valid reasons for this order and to arrive at conclusions you would be willing to live up to, day after day, in the routine of you duties, whatever they may be?

It will not do to pooh-pooh these things aside; in fact, if you feel that way now you would better recognize the feeling as one of the early symptoms of incipient super-specialization and that you are suffering from a slight attack. For these considerations are not exclusively exalted and general policies reserved to occupy the mind of the president only; they are common realities that enter in one way or the other into the everyday work of the employee down to the humblest station.

There is, for instance, the blighting bane of hide-bound department narrowness causing each to constitute itself into a stronghold surrounded by a spiked fence, barring interference, no doubt, but helpful suggestions as well. Out of this condition grows a tendency towards diminishing interest in the welfare of the company as a whole, that in severe cases might even cross the zero line of indifference. The neglect of general over-all considerations may lead to reckless department over-enthusiasm, the effects of which are not at all beneficial. For instance, it is quite feasible that the purchasing department might save enough money on lubricating oil to ruin your equipment and demoralize your engine-room force. Frenzied new-business-getting methods are occasionally so successful that a customer's first bill proves to be his last. Rules and regulations are now and then so explicit, and various requirements follow each other in such logical and extended sequence, as to protect the company effectively against the persistent assaults of anxious prospects. It is entirely possible to collect your bills so promptly and sharply that the amount collected will be materially reduced. If matters of this kind are allowed to drift there will finally result a fatal case of what Fagan has correctly designated as "department paralysis."

The influence of excessive specialization on the individual employee is to develop exaggerated ego. The narrower a man's horizon becomes the greater his own importance looms up to him within it. In so far as a man realizes that the part he plays in the business, no matter how small that part is, is important, he is wise; but when he begins to imagine that his part, no matter how great it is, is the

only important part, he is foolish; he simply consigns himself automatically to the category of little men.

The specializing process of a large organization inclines towards rigid mechanical treatment of men, and this should be counteracted by judicious application of a high grade humane lubricant to avoid grinding and cutting. The fact that a corporation has no soul imposes upon every employee, high and low, the duty to clearly demonstrate on every occasion that he has one. Practicing that doctrine will of itself eliminate the very worst consequence of super-specialization that is likely to arise—I mean the specialization of responsibility.

No doubt, in most cases, it is physically impossible and theoretically and practically wrong to meddle with things not in the line of your immediate duties, but if you have the spirit of true loyalty to your company, there is no better way of exercising it than by quietly and persistently doing your part in guiding everything that needs correction into the proper channel for immediate attention.

No concern can live and prosper that does not recognize and properly reward true loyalty, and nobody knows that better than those who carry the responsibility for success. Going down the list of employees we come to a certain well-defined point above which we anticipate, expect and count without question or reserve upon loyalty under all circumstances and conditions, while below that point we are in doubt. To succeed in pushing that point down the list until it reaches bottom is an accomplishment of which the best might be proud.

The task requires a man able to exercise the highest qualities of character, a man of unvarying fixity of purpose, indifferent to the ridicule of the facetious and the malice of the jealous and, above all else, a man of broad-minded fairness, rising above the arrogant narrowness bred by intense super-specialization. Men of this class are now coming to the fore in every quarter and we, in our humbler stations, cannot possibly serve ourselves, our company or, for that matter, in a broader sense, our country, better than by giving them loyal assistance to the best that is in us.

WINDING OF DYNAMO-ELECTRIC MACHINES—II

SMALL DIRECT-CURRENT MACHINES

THREADED IN TYPE

G. I. STADEKER

THE smaller types of industrial motors, between one and three-quarters and five horsepower, are usually built with partially closed slots, though as a rule the slots are not skewed. This necessitates some form of wire wound threaded-in coil. The form shown in Fig. 25 is that generally used, on account of the ease with which such coils can be formed and assembled in the machine, and because they require little room for the end connections.

THE CORE

The core used for these motors is generally mounted on a four-arm spider as shown in Fig. 26. A key-way is slotted in one of the arms in which is inserted a key to hold the core from turning. The punchings are slipped one at a time over the spider and key. On the smaller machines, the first three or four laminations at each end are made of heavier steel and serve to stiffen the core and prevent vibration. At one end they are held in position by a collar on the spider arms. After the core is assembled with laminations and ventilators in proper order, the end frame which holds them at the other end is placed in position, the core is compressed in a jig by a heavy screw until the key slots on the spider and the end frame coincide, and ring keys are inserted into these slots, holding the core rigidly in place. The assembled core and spider are then pressed onto the shaft, and oil throwers are shrunk on. In the smaller machines the commutator is usually pressed on the spider before the armature is wound.

FIG. 25—MOULD WOUND COIL
Threaded in Type.

WINDING THE COILS

Each complete coil contains three or four single coils of double cotton covered wire wound from separate reels into one unit. The leads of each single coil are provided with extra insulation in the

form of woven cotton sleeves which, as a distinguishing mark, are of a different color on each pair of leads. In winding the coils, a sleeve to protect the leads is first slipped down to the end of each wire and adjusted so that it will reach about three-quarters of an inch along the body of the coil, the ends of the wires being fastened on the mould. As the spindle is re-

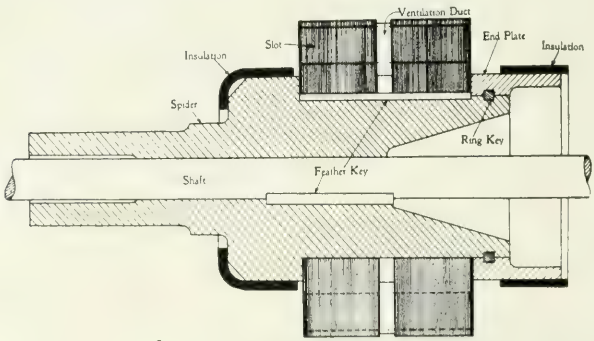

FIG. 26—ARMATURE SPIDER AND CORE

volved slowly the winder guides the wires into the mould, placing strips of tape under them at the corners, and keeping them under considerable tension to make them conform closely to the shape of the mould. On the last turn another sleeve is slipped down each wire to protect the leads, extending along the body of the coil a sufficient distance to be bound in place with the tape which was previously inserted. The leads are then cut off at the proper length.

INSERTING THE COILS

The slots are insulated with an outer protective layer of fish paper about three-quarters of an inch longer than the slot, and two inner cells of treated cloth, one enclosing the lower, and the other the upper coil, as shown in Fig. 27. On machines having a terminal voltage of 500 volts or over, it is customary to insert a third cell of treated cloth, which is placed next to the fish paper cell, and encloses both the coils, insulating them more fully from the core.

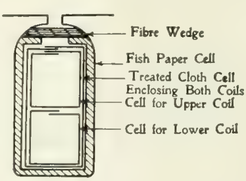

FIG. 27—SLOT INSULATION

These cells are cut to such a width that they will project about an inch beyond the slot openings, thus serving to guide the strands into the slot, and to protect them from mechanical injury during the winding operations.

Since the slots are partially closed, all the bottom coils can

be inserted as shown in Fig. 28, before the top coils are placed in the slots. The individual strands are forced into the slot with a flat fibre drift. As each coil is put in place the lower leads are inserted into the slits of the proper commutator bars, care being taken that the different colored leads are connected always in the same order. After all the coils are in position in the lower half of the slot the projecting edges of the inner cell enclosing the lower coil are cut off close to the slot and folded in, using the fiber drift and a mallet to force the wires and cell into position in order to

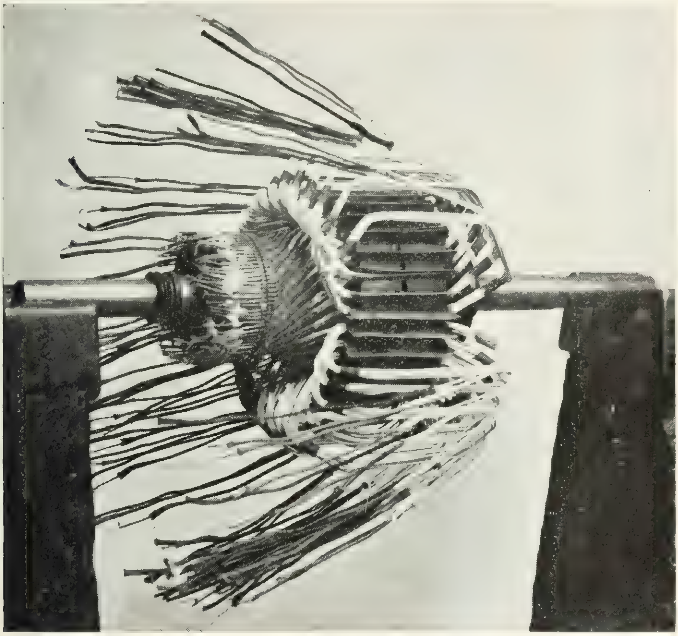

FIG. 28—ARMATURE WITH COILS IN LOWER HALF OF SLOTS

make room for the upper coil. The unprotected wires which cross the end of the core are then taped with cotton tape for about two-thirds of their length, starting up close to the core and enclosing the ends of the lower cells which project from the slot.

After all the lower slots have been filled, an upper cell is inserted in one of the slots to receive the top coil. Facing the commutator, the throw is counted in a counter-clockwise direction from the slot just prepared, to determine which coil should go into this slot. The proper coil is bent into better shape; its strands are then waxed and inserted into the slot. The edges of the projecting cell or

cells are then clipped, folded in and hammered tightly into place with a mallet and drift. A fiber wedge is then driven in over the coil, by means of the wedge driver shown in Fig. 29. This wedge driver consists of a hollow rectangular piece of steel, fitted with a sliding steel strip of about the same size as the wedge. The wedge is inserted into the driver, its end is then beveled and started into the slot and it is driven into position by tapping the steel strip with a mallet. A piece of cotton tape is then firmly wrapped around the coil and the projecting tip of the wedge close up against the core to insulate the end connections out to the taping previously placed in position, the end of the tape being glued.

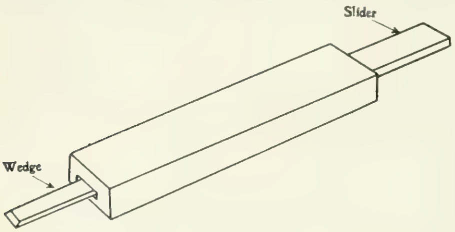

FIG. 29—WEDGE DRIVER

After two or three of the top coils have been placed in position, one or more treated duck strips are inserted between the end connections of the upper and lower coils, where they cross each other at the ends of the armature, as shown in Fig. 30. As the upper coils are put in place these strips are wound around the armature so that they finally form a complete band of insulation between the upper and lower coils. Each coil as it is put in place is shaped at its ends with a mallet and drift so that all coils nest snugly one against the other and present a rigid construction when the armature is completed.

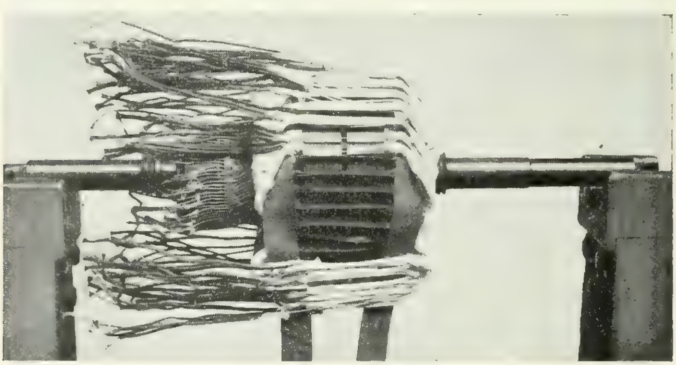
FIG. 30—PARTLY WOUND ARMATURE
Showing two coils completely inserted, and treated duck blankets in place.

The upper coils are then connected to the commutator, the colored leads forming a ready means of distinguishing the coils. Before soldering, the armature is tested for grounds with 1 200 volts, and for short-circuits and open circuits by means of an alternating-current magnet, such as shown in Fig. 31. When the magnet is placed against the armature, an alternating flux passes through the core, generating electromotive forces in the windings. If the winding is correct, no current will flow, as the voltages will balance one another. A sharp piece of steel, or a knife blade, is passed around the commutator, short-circuiting in succession the coils which have one side under the magnet. A decided sparking, indicating a potential difference between the bars, shows that the coil is in good condition. Absence of sparking indicates either an open or a short-circuit. The latter can readily be determined by running a light piece of sheet iron over the surface of the armature, bridging the slots in succession. If there is a short-circuit in one of the coils which has one side against the magnet, a local current will flow through this coil, generating magnetic fluxes, which will attract the iron. If there is no sparking at the commutator, and no local magnetic flux, an open circuit is indicated.

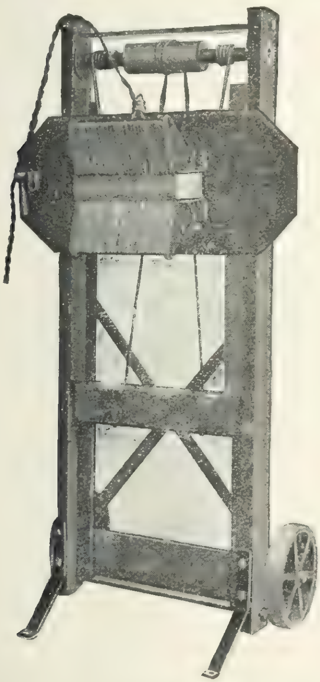

FIG. 31 — TESTING TRANSFORMER FOR LOCATING SHORT AND OPEN-CIRCUITS

If no fault is discovered the commutator is soldered, turned, filed and sand-papered to a smooth finish. The armature is then taken to the banding lathe, and the ends of the coils are hammered down until their diameter at the ends is no greater than that of the core, care being exercised that the insulation is not injured by the mallet.

The armature and leads in machines which are liable to be subjected to dust and dirt, as in many industrial applications, are protected from the dirt by a canvas hood. This is put in place on the banding lathe. A conical hood, which tapers just enough to

fit tightly over both the armature and commutator, is slipped over the shaft and the small end is drawn up over the leads and turned inside out with the body of the hood laid back over the shaft away from the armature. This end is then bound over the leads and commutator neck with twine. The hood is then turned back over the armature, and another layer of binding twine is wound over it near the commutator. Two bands of cotton tape, separated by a band of varnished cement paper are then wound over the hood and end connections near the core as a base for the banding wires, and the whole is tied down with twine as shown in Fig. 32. As the armature is rotated in putting on the twine the hood is stretched tightly over the end of the armature by hand. It is then cut off even with the end of the core and shellaced. If the machine is to be subjected

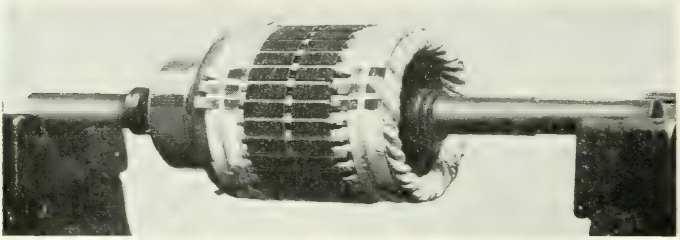

FIG. 32—ARMATURE READY FOR BANDING

to exceptionally severe operating conditions, as in automobile service, section are slipped under the temporary banding twine at intervals is used at this end, bands of cotton tape and cement paper are wound over the conductors to protect them from the banding wires. and tied in place with twine.

BANDING

Short strips of tinned copper, about 0.02 by 0.25 inch in cross-section are slipped under the temporary banding twine at intervals of two or three inches, two extra ones being used where the banding is started and ended. The tinned steel band wire (No. 14 to No. 17, B. & S. gauge) is fastened to a peg slipped into an air duct. or, if there are no air ducts, is tied to the end of the banding twine, and is guided around the core so that it crosses itself, relieving the strain from the peg, and is then guided over the copper strips on the taping. After two or three revolutions have been made the string can then be cut off and the binding wire is wound in snugly fitting rows across the protecting tape. After the required width

has been laid, the copper strips at the start and end are turned up, clipped off so that about one-quarter inch projects from under the banding wire and are bent over so as to hold the wire in position. Without clipping the wire, it is guided across the core, still under tension, to the taped part of the opposite end and this is likewise banded to within about a quarter inch of its edges. The clips at the beginning and end are then bent over and soldered, and the wire is cut off. The wires are then driven close up together, all the clips are bent over and the wires are soldered in place, care being taken that the tie spots are not melted until after the rest of the banding has been soldered. No acid should ever be used in connection with the soldering operations, a solution of rosin in alcohol being recommended. All surplus turns and cross-overs are then removed, and

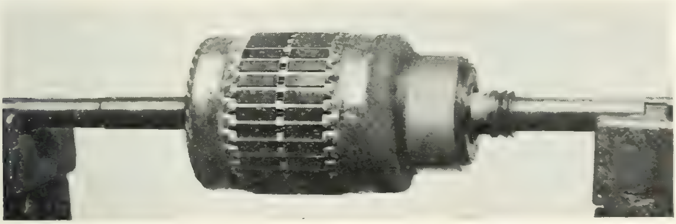

FIG. 33—COMPLETED ARMATURE

the armature is completed except for balancing. Fig. 33 shows a completed armature with the bands in position.

SMALL DIRECT-CURRENT MACHINES

OPEN SLOT WINDING

For open slot machines, above about five horse-power, the coils are made of either wire or strap copper. They may be of the mould wound, former wound or pulled type and are fully insulated before being inserted into the slots. The coils in most general use are shown in Fig. 34. The short type coil, shown at the left, having part diamond and part involute end connections, lends itself readily to small machines, since, as it is almost square, the total length of the armature may be made smaller than if ordinary diamond coils are used. The former wound diamond coil shown at the right is used on the larger sizes. The pulled diamond coil* can, however, be wound more rapidly and cheaply than either of the above, and the tendency is to use this type wherever it is applicable.

* See *J* Fig. 3 in the first article in this series in the June, 1910, issue.

The insulation is applied to the coils after they leave the coil winder, who merely ties them with string, so as to hold the strands in place, though in some cases a thin paper cell is pasted around the body of the coil by the winder. A standard insulation for small machines consists of a wrapper of treated cloth over the body of the coil, held in place by a non-overlapping layer of cotton tape. The end connections are protected by an overlapping layer of cotton tape, and the leads are further protected by cotton sleeves. The entire coil is then dipped in insulating varnish and baked.

The wave winding is almost universally used on the smaller types of direct-current machines of multi-polar construction. This winding has but two paths through the armature, regardless of the number of poles, and half the coils in the armature are connected in series in each path, whereas the lap winding has as many paths

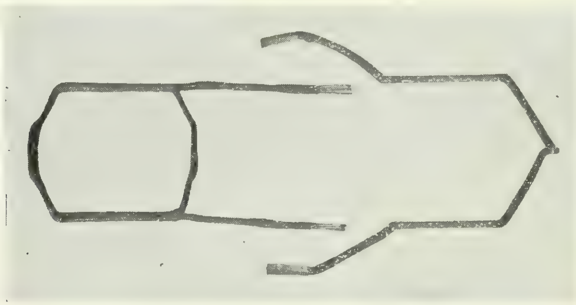

FIG. 34—WIRE-WOUND SHORT TYPE AND STRAP-WOUND DIAMOND COILS

as there are poles, and a correspondingly smaller number of coils in series. Assuming, for instance, two four-pole armatures, wound with coils of the same number of turns and same size conductors; if all are connected in a wave winding, the armature will be suitable for double the voltage at half the current that would be used with the same armature connected for a lap winding. Thus on small machines, where the number of turns is necessarily limited, the wave winding is usually much cheaper and easier to install.

THE CORE

Two types of slots are employed, as shown in Fig. 35. The one to the left has wedge grooves in the teeth, through which wedges can be driven, thus securely holding the coils in position. With the other type of slot, the banding wire which is wound in the banding grooves of the armature and over the end connections is relied upon

to keep the coils in the slots. One standard core of the open-slot type may be used with several types and sizes of machines. The only change usually necessary to adapt it to a slightly smaller coil, is to fill in the slots on the sides and below the coils so that the wedges or banding wire will press firmly against the top of the coils in the slots, thus preventing any motion of the coils which might chafe the insulation. The "fillers" usually consist of strips of treated fullerboard or treated wood.

In the larger machines, a finger plate, shown in Fig. 36, is used to confine the laminations at each end, and ventilators are inserted at regular intervals. When no wedges are used part of the laminations may be of smaller diameter than the standard size, leaving grooves in the armature at intervals for the banding wires. These are termed "short" laminations. Thus in a single core there may be two classes of laminations besides the finger plates and ventilators. The specifications for assembling the core usually state the weight of the long laminations to be put in place before reaching the first banding groove, the number of short laminations in the first groove, the weight of long laminations between grooves and ventilators, and so on until the entire core is built up. The laminations are weighed out and piled up in their proper order for assembling, and are placed one by one over the spider until about a quarter inch has been assembled. Then, in order to facilitate the assembling, a flat bar of iron may be inserted into one of the slots, the top end projecting an inch or so above the top of the key. This serves as a guide to the laminations and saves time in fitting them over the key. When a couple of inches of the core has been assembled the laminations are rammed down tight with a hollow

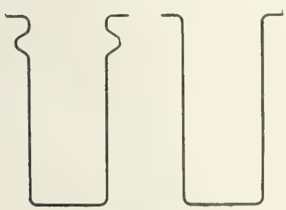

FIG. 35—OPEN SLOTS
With and without wedge grooves.

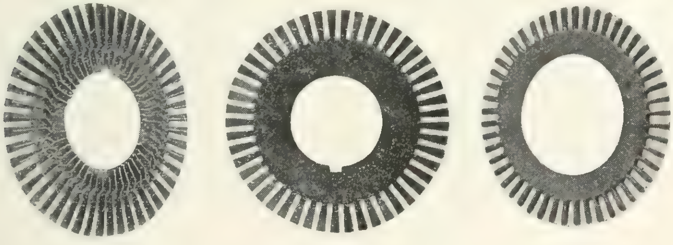

FIG. 36—VENTILATOR, STANDARD LAMINATION AND FINGER PLATE

cylinder of metal. After all the laminations have been put in place, the top finger plate is put on, the core is placed in a jig provided with a screw and the laminations are compressed until the ring key can be inserted into the keyway between the end frame and the spider. A flat bar of iron called a shaping drift, which fits snugly into the slots, is hammered successively into each slot, thus forming a smooth surface. A file is then used to further smooth up the inside and bottom of the slots and remove any burrs.

INSERTING THE COILS

The core is next mounted horizontally, a lathe being commonly used for this purpose, and the slots are filled with fish-paper

FIG. 37—INSERTING THE COILS
For simplicity, armatures wound with short-type coils only are illustrated. The processes for other coils are practically similar.

cells, about one-quarter inch longer than the slots, and wide enough to project about an inch above the entrance to the slots, as shown in Fig. 37. These form a mechanical protection for the coils and also act as guides or runways through which they can be easily slid into place. The corners of the projecting edges are cut off to keep them from interfering with the insertion of the coil. The winder inserts a coil in two slots whose separation is determined by counting off the specified throw, and forces the side that is to go into the lower

part of the slot into position by laying a flat fibre drift over it in the slot, and tapping it with a mallet. If it does not fit snugly, side fillers of fullerboard or wood should be inserted so that there can be no possible motion. A coil is then fitted similarly into the adjacent slot and so on around the armature until coils equal in number to the throw minus one have been put in place. The upper side of the next coil inserted will then fall in the same slot as the lower side of the first coil placed in the armature. Each slot, when the coils are all in place, will thus contain two separate coils, one above the other. Each top coil is driven firmly into place with

FIG. 38—SHAPING THE COILS
Throw coils raised to allow the last coils to be inserted in the slots.

the drift and mallet. The edges of the cell are then cut off, and if wedges are employed to hold the coils in the slots, the sides of the cell are bent over so as to get them under the wedge, which is then driven into place, making a tight fit in the grooves and bearing down hard on the coils. The end connections are shaped by means of a winding drift. This consists of a steel bar about 12 inches long, one inch wide, and tapered in thickness from one-half to one-eighth inch, having all the corners rounded and smooth. The tip of this drift is placed against the inner side of the end connection of the coil and tapped with a mallet, forcing the upper part of the end

connection out from the armature, and away from the lower half. Fig. 38 shows a workman performing this shaping operation. Each coil as it is put in place is similarly shaped so that when the armature is completely wound a circular air chamber is formed between the upper and lower halves of the end connections at both front and rear. This process is continued until the first slot is again reached. This slot and several succeeding ones contain a top coil but no bottom one. These coils, called the throw coils because they cover a part of the armature equal in number to the throw, must be removed, as shown in Fig. 38, being retained in their approximate position by the other side of the coil, which is in the bottom of a slot. The bottom coils are then put in place and the throw coils

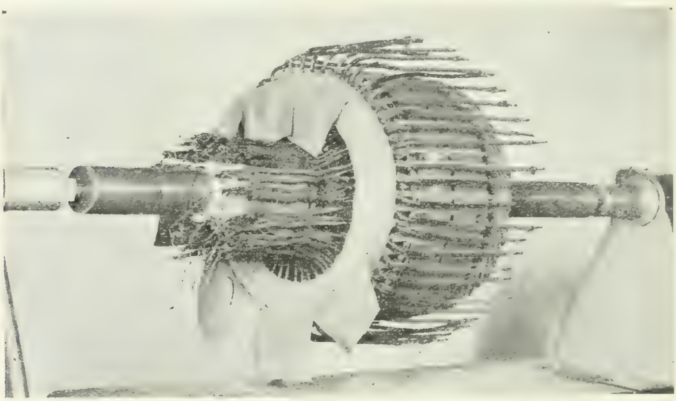

FIG. 39—ARMATURE WOUND, LOWER LEADS IN POSITION

are replaced and wedged into a permanent fit. After all the coils are in place the winding is trued up and tested for grounds. A friction cloth blanket is then placed over the end connections on the commutator end, as shown in Fig. 39, as a protection for the leads.

When wedges are not used to keep the coils in place, some means must be provided to prevent them from becoming loosened from the slots during the subsequent operations before banding. To accomplish this, a single band of wire is tightly fastened around the coils at each end of the armature.

When completely wound the armature presents a rugged, compact mechanical construction and it is practically impossible for the ends of the coils to become distorted as a result of centrifugal strains. Throughout the whole winding operation, great care must be exercised not to chafe or damage the windings in any way. As

the insulation on the coils is stiff and hard, having been dipped and dried, it is generally seriously injured if it tears at all. Hence, during the winding process it is necessary to be particularly careful to repair a damaged coil before proceeding further. To do this, the damaged half of the coil should be removed from the slot, and all of the insulation removed from the straight part. An overlapping wrapper of treated cloth is then applied and around this a protecting covering of cotton tape. The ends are glued and the new winding is shellaced. To dry the shellac, a lighted match is touched to it, the alcohol, which is used as a solvent, burning with its characteristic blue flame. A yellow color in the flame indicates that the tape has started to burn and at points where it is visible, the flame should be smothered. However, the heat of the burning shellac is seldom sufficient to ignite the tape, and the blue flame burns itself out. The

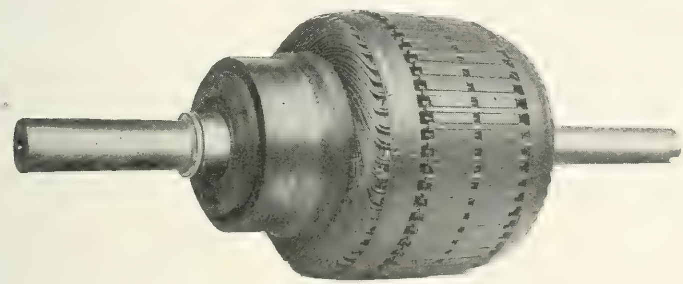

FIG. 40—COMPLETED ARMATURE

coil is then perfectly dry, and can be inserted in the slot. This method of repairing is permissible only on very small armatures; on larger sizes damaged coils should be removed, reinsulated, dipped and baked, or new coils substituted. Because of the stiffness of the insulation, it is good practice to soften the armature leads with armalac or some similar compound at the points where they leave the bottom coils, at which point any break resulting from handling while connecting to the commutator is most liable to occur.

In most machines of this type the commutator is pressed on the spider after the winding is in place. The leads are then connected to the commutator, and copper wedges are driven into the slits over the leads to hold them in place. The commutator is then soldered, turned and polished, and the armature is banded. After being balanced and tested, the armature is painted and is then ready to be mounted in its frame.

RATE MAKING FOR PUBLIC UTILITIES

THE MADISON CASE

PERCY H. THOMAS

PUBLIC service companies, gas and electric, and street railway corporations are subject to certain unique conditions arising from the close relations existing between such supply companies and the community and particularly the public authorities. At the present time there is a rapidly growing practice of subjecting the rates and the service in general to the supervision of some sort of governmental commission. There arise in the working out and development of the methods of these commissions many difficult and complex questions which, while not strictly electrical, are of such a nature as to fall naturally to the engineer for solution.

A decision of one of the oldest and most careful of these commissions has recently been handed down in a case involving the revising of commercial rates for light and power in a combined gas and electric plant. This decision*, which was rendered only after a very exhaustive discussion and consideration of the case and which is very complete in its explanations and establishing of principles as to the methods followed, is the occasion of the present discussion.

The logic of the view usually taken of the status of the public service companies by the law-making bodies and their commissions seems to be roughly as follows:—Companies distributing light and power to municipalities or furnishing general transportation facilities can do so only in virtue of privileges granted by the community, such as the use of streets for the running of lines. The privilege of such use of the public property is granted only for the benefit of the public and not for the benefit of the service company, and it is the intention of the community to grant opportunity to the service company for only enough profit to insure the willingness of capitalists and managers to install and operate plants.

Again, it is found by experience that the supply of electricity and gas to a municipality, leaving out of account street railway systems, tends properly from the viewpoint of economy to be a monopoly, as two competing plants will require nearly double the cost for distributing systems. In a number of other ways, also, competition in such service is found unsatisfactory. Now with a monopolistic business, dealing in practically a necessity,

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*Decision of the Railroad Commission of Wisconsin in the case of the State Journal Printing Company vs. The Madison Gas and Electric Company, rendered March 8, 1910.

it is obviously possible under favorable circumstances that the service company may charge exorbitant rates. In some few instances it is undoubtedly true that the service companies have earned large returns on their investments, and this fact, as well as the semi-unconscious assumption on the part of the public that because the theoretical possibility of extortion exists the practice is widely existant, has lead to the the general belief among those not familiar with the real conditions that they are being taken advantage of by the service companies. As a matter of actual fact, however, it is very doubtful whether more than a small proportion of these companies are earning even the average returns on their investments that are secured by successful companies in other lines of work.

However this may be, the so-called public service commissions have been and are still being created with powers to supervise the rates or charges of service companies, including the power of examining the financial condition and history of the companies and of limiting the maximum rates to what are very easily called "reasonable" rates. There was a time, some years ago, when the municipalities made an effort to escape what some considered extortionate rates by installing municipal light and power plants, but these were not in general found either satisfactory or economical, although in the relatively simple matter of street lighting, municipal plants have been more successful.

In view of the frequently found feeling of public officials that service companies are getting more than a fair return on their investments, and of the general tendency of those not experienced in the handling of such plants to underestimate the cost and difficulties of their operation, the owners of public service companies have often feared that the commissions would make large reductions below the actual fair value of their plants by the close limitation of the maximum rates. There seems to be no general reason, however, why a fair-minded commission should not do justice to the public without lessening the legitimate investment value of the service company. But, however real justice may be affected, the commissions are appointed and must make their investigations, so that it is a "condition and not a theory" that confronts all parties. The matter of rate making should thus be carefully studied and knowledge of this subject be as widely disseminated as possible.

The Madison case is perhaps the most complete of the light and power company rate investigations yet decided, and it is the purpose of the present article to briefly point out the reasoning and

conclusions of the commission therein. The net result in this case, which involved an old and rather prosperous company, was an order readjusting and moderately lowering the rates.

The procedure in such cases is for a complaint to be made by some citizen or authorized body asking for a reduction of rates, giving grounds therefor; and the service company and complainant, and in important cases others interested, are permitted to make arguments and bring forward testimony to support their positions. The commission, with its engineers, then goes over the whole matter and arrives at some definite conclusion. In the Madison case many witnesses were called, including some of the best-known experts in the country, and the service company's books were analyzed in great detail, going back over some twelve or thirteen years, a year or two being consumed by the commission in the process.

The broad problem was to determine whether the rates of the service company were "reasonable" or not within the meaning of the laws. The Wisconsin law says:—

> "If upon investigation the rates, tolls, charges, schedules or joint rates, shall be found to be unjust, unreasonable, insufficient or unjustly discriminatory or to be preferential or otherwise in violation of any of the provisions of this act, the commission shall have the power to fix and order substituted therefor such rate or rates, tolls, charges or schedules as shall be just and reasonable."

In theory at least the commission is not to set the actual rates that shall be paid, but to set a limit above which it considers rates to be unreasonable, leaving the service company to charge lower rates if it so chooses, thinking perhaps to increase or otherwise strengthen its service. But there remains on the company this limitation, that it must maintain the rates equitable as between different consumers similarly situated, in any rate reduction below the commission's maximum. They may not reduce the rate to favored persons, leaving it unchanged for others who make a similar use of current or gas.

Thus, not only must a determination be made of what is a just and reasonable rate of return per unit of capital involved and of the amount of capital upon which this return shall be reckoned, but also at least a rough estimate must be made of the relative cost of the service of different classes of customers to avoid unreasonable discrimination.

It is further a well recognized principle that each case must

be considered on its own merits and that what may be a fair rate in one city may not be in another, so that ratings in one are not binding in the other. This determination of what rates are reasonable in any particular case has turned out to be very difficult, as will appear from the discussion to follow. There are many conditions and values not capable of exact determination, nor will different well-informed and fair persons agree on amounts nor methods.

But there is one thing more important than exact justice in these cases. There must be a definite and final decision of some sort so that controversy may be actually terminated and the public and the owners know where they stand. This the commission apparently has the authority to make, though the courts have presumably the right to review their decision.

In spite of some indeterminate factors the commission has been obliged to make the best decision they could, settling on definite and precise figures for the actual rates involved. It is thus perfectly manifest that many minor points in the decision must be in a certain sense illogical and in some degree unfair to one party or the other, but it is the apparent intention of the commission to make such discrepancies small in amount and to have them balance one another as far as practicable. With this introduction, the reasoning of the commission in the Madison case will be readily followed. It was necessary to determine:—

The value of the property;

The reasonable rate of return; and,

Such a chedule of charges as would produce the rate of return determined upon and which would at the same time distribute the burden of it equitably among the several classes of consumers.

In determining each of these three quantities, it was found that there was much difference of opinion as to many of the component items, so that different persons and different tribunals would tend to arrive at somewhat varying results. These items about which there is a general difference of opinion are of especial interest to electrical engineers and it is partly because the Madison decision goes so fully into these details that it is here considered.

VALUATION OF PROPERTY

It is clear that a definite valuation of the property must be arrived at before it can be determined whether, according to any rate that may be chosen as reasonable, the actual net income will exceed the allowed rate. The method to be used in arriving at this valua-

tion gives at the start a matter bringing forth a great divergency of opinion. The difficulty of the matter is especially great, for there is at stake not the mere abstract principle as to which is the logical method of arriving at the result, but the actual effect of the conclusion reached on the property of those owning the service plant. The smaller the valuation arrived at, the less the actual income that will correspond to the allowed rate of net earnings and the smaller the value of the property, for if the rates in force should produce a revenue beyond the allowed percentage, they will be pronounced unreasonable and reduced.

Several methods of valuation have been proposed. For example, if the books of the company have been properly kept for this purpose, the value of the property might be taken as the total amount that had been spent on the construction and equipment of the plant new including all proper and necessary expenditure of new money that might have been put into extensions of the plant, either money taken from the proceeds of stocks and bonds or from net earnings. This is not found, however, to be a satisfactory method of procedure. It is the purpose of the commissions to allow the maximum rate of return only on such capital as represents plant or equipment "used and useful" in the service of the public. That is, if any of the capital of the company was used for some other purpose as, for example, to serve some private purpose, or, if by incompetent management, the cost of the plant had been made unusually large, the commission does not expect the valuation to include such excess items, for it would not be equitable for the public to pay returns on capital used in other service or lost through improper handling. Thus, it is not possible to take the book showing as the valuation without verifying the result to see that all the money there entered was actually used and useful in the service of the community and further was as economically expended as is usual in such work. This requires a method of checking up the book showings, and the checking method then becomes the real method of valuation.

Again, it might be said that the plant should be valued at a figure on which the net earnings will show the allowable rate of return, whatever that may be. But this is arguing in a circle, for clearly, if through monopoly, privilege or other means, the rate had been forced unreasonably high, this procedure would result not in showing this fact, but to give a higher valuation to the property. Were there to be no supervision or legal limitation of earnings for

these public service corporations, such a monopoly privilege, and such high rates would probably mean an actual increased investment value. But as it is the purpose of the commission to allow only such rates as will attract the necessary capital and no more, that is, to offer earnings equal to those in similar lines of activity, such an excess valuation would not be permitted.

And, similarly, with other methods of valuation which are proposed, each has some practical or logical flaw in it, and finally the best available must be chosen. In the present case, one method was actually settled upon and the result compared with the results of other methods for purposes of verification and checking. The method selected was to determine, as an engineering matter, the cost of reproduction of the plant new, under circumstances similar to those under which it had actually been constructed, that is, only part of the plant initially and extensions piecemeal, taking into account the extra cost of constructing the extensions without interrupting service. This reproduction cost was considered item by item by the commission and by both parties to the case.

As both gas and electricity services are maintained, two separate valuations were made, one for the gas plant and one for the electric, and all items common to the two were apportioned between them.

The real estate owned by the company made one very important item in the valuation. A valuation of real estate is hard to determine without an actual sale. No two parcels are exactly alike in value and, furthermore, any one parcel may be worth more to one man than another. If an owner must sell, the price he obtains will be much below that he can obtain if he disposes of his land to a man who must have it, as, for example, for some plant extension. Therefore, even if a sale of a plot of apparently equal value in the same neighborhood can be found and occurring at about the same time, the price may not show the real value of the land for rate-making purposes, for the sale may have been made under special circumstances. Fortunately, this valuation of land is not a new thing and the methods of procedure are pretty well worked out. While this procedure will differ somewhat in different cases, one common plan consists in getting an average selling price from actual sales for a considerable number of parcels, as nearly as possible equally well located and of similar advantages and of inferring as a matter of judgment from these the value of the lot, using as a guide the relative tax assessment valuation of the various lots and the lot to be valued. It is found by actual investigation that the assess-

ment valuations are often very uniform in their relation to actual average sales and are hence of great assistance, since they are assumed to be relatively independent of the interests involved in the particular case under consideration. All the special features bearing on the utility of the real estate should be considered, such conditions as available railroad connection, water for condensing purposes, grade of the surface, etc.

Having arrived at the cost of the land, the cost of the actual labor and material to construct a plant is not so difficult, after the market price of labor and materials have been agreed upon.

As a part of the total cost, the commission allowed an amount equal to five percent of the construction cost for engineering expenses, basing this on the total cost of the present plant, in spite of the fact that much of the plant was built as extensions and the salaried staff of the company must have done much of this work without much extra compensation.

Four percent was allowed for the interest on the capital necessary for the work during the construction period. This value was taken on the basis that interest at six percent per annum must be paid on the whole capital for half of the time involved in construction. The commission considered that all but temporary balances should draw such interest as might be obtainable.

Three percent was allowed for legal work, expenses, organization, casualty insurance, omissions and contingencies. This percentage the commission stated would be far too small in many cases, but concluded from the fact that the books showed very small legal expenses or organization expenses, and since the omissions and contingencies should be very small under the very close scrutiny given this case, that three percent was a fair value.

The commission recognizes the extra cost of plants that are constructed piecemeal; that is, a nucleus is first installed and this extended later, and takes account of this fact by choosing unit costs of material, etc., to correspond with the size of the units of construction in which the plant was built.

The working capital is included as a part of the valuation of the plant. This sum is allowed at $45 000 to $50 000, the final total valuation allowed for the plant being about $900 000 to $950 000, including both gas and electric. It was claimed by the company that a much larger allowance should be made for working capital, and especially in view of the necessity of supplying electric energy

and gas for more than a month before the bills could be collected. The commission concluded, however, that the company could nearly balance the accounts receivable against the accounts payable by buying on thirty days basis, on which basis the commission concluded that supplies could be bought as cheaply as for cash.

Thus a definite valuation for the system or plant was finally arrived at upon which the commission held that the company was entitled to secure the maximum allowable rate of returns, provided the plant could produce such earnings. The valuation arrived at by this process was checked up by comparison with the book showings. It seems that the plant was purchased by the present owners during the year 1896, for $323 000, and the commission took this as a starting point, on the ground that the actual purchase price should measure the initial capital invested by the present owners and that any further equity that might exist for the original owners was no affair of the present owners, as no injustice to the original owners would be corrected by concessions to the present owners.

It was further found that the sums actually spent for new construction and extensions added to this $323 000, as nearly as these amounts could be determined from the books, was not far from (in fact, was a little less than) the valuation already arrived at. viz: that of the reproduction cost. And, again, it was found that while the books started by the present owners showed for the property purchased at $323 000 a value of $750 000 in 1896, that the books in 1908 showed about the same excess over the valuation of the commission based on reproduction cost as did the original book value over the purchase price. Thus as far as this study of the books could be relied upon, the commission valuations seemed to agree very well with the data in the records of the company.

But the commission valuation was checked up in still another way. Taking the original 1896 purchase price as the correct value at that time, a value was determined for the next year by adding thereto the cost of all extensions, including 12 percent for engineering, interest, contingencies, omissions, etc., a certain sum for depreciation, and eight percent on the investment (the maximum allowable "reasonable" rate of return determined upon), together with an allowance for the increase in the value of the real estate, and then subtracting from the sum the net earnings for the year. The logic of this arrangement is that any extensions increase the permanent investment proportionately; that in view of the deterioration of the plant a certain sum should be set aside each year out of the income

to maintain the investment intact; that the value of the real estate increase should be allowed to proportionately increase the investment of the company; and that if the net earnings do not equal the permitted eight percent on the investment, the difference should be accumulated for future payment, and that the same rate of return should be realized on this as on any other capital that the owners must put up to bring the company to ultimate success. This is clearly logical and only fair to the owners. It might be thought that the yearly sum set aside for depreciation should be subtracted from the net earnings instead of being added to the capital, but it is the intention of the commission that a separate depreciation account or fund shall be carried on the books so that there will be an actual accumulation of capital to balance the actual loss of value in the apparatus. Depreciation is thus better represented as an addition to the valuation than by subtracting from the net earnings, especially as it is possible that the depreciation assignment might in some years exceed the available net earnings. In any event, the net result of either process will be numerically the same.

Having obtained this second yearly valuation, another valuation is obtained for the next year following, and so on up to the year of the proceedings, 1908. The value of $879 000 approximately was found for 1908, which should be compared with the value $925 000 to $950 000, found by the method of reproduction cost. The fact that the latter is the larger indicates that the plants have earned somewhat more than eight percent on their investment, taking their full life since 1896 into account. But as there is always a good deal of arbitrary assumption in arriving at such results and as the books did not permit of a clear distinguishing of sums spent for repairs from sums spent for renewals and new construction, the commission did not feel justified in taking the smaller value of the two, that arrived at by yearly steps, for the actual valuation. Thus, by still another method the commission endeavored to establish the reasonableness of the actual valuation used as a basis for their final decision. The valuation actually used was $947 000.

There are two features of this valuation that require a little further consideration, depreciation and the so-called "going value."

DEPRECIATION

The reasoning of the commission as to depreciation was somewhat as follows:—

The investment once made is to be taken as fixed and permanent except as far as it may be increased by new capital put into

extensions or by other appropriate means. Much of the plant and apparatus, however, will have a limited life and must be replaced at the end of a certain term, however carefully or well it may be maintained. This life will be different for different parts of the apparatus, but each will have some limited term. For instance, the buildings will have a very long life, while storage batteries and arc lamps will have relatively short lives, and transformers and generators will be intermediate. The commission arrived at a composite average life for the electric plant, by considering all the items individually, as 17 years, and similarly 30 years for the gas plant. At the end of its life each part of the apparatus must be replaced, thus requiring the expenditure of more capital and increasing the capitalization of the plant. To avoid such an increase there is set aside each year from net earnings such a sum as will be sufficient to replace all the apparatus of the plant piece by piece by the end of its life.

But the replacements do not all come at the same time. They are very small at first and begin to have some importance only after a few years, and then are greater or less year by year until the whole apparatus has been replaced. Thus, if the yearly reserves for replacements or depreciation are equal or rather in proportion to the amount of depreciable property, as they manifestly should be, there will be a considerable accumulation of the fund during the life of the plant which will be expended in large replacements later. The replacements will in the long run balance the yearly payments. There will be, however, at all times after the initial start a considerable balance in the depreciation fund, for there will always be some accumulation waiting for a later replacement. Interest can be obtained from such a permanent balance, and the commission considered whether account should be taken of this interest. They finally decided not to allow any interest on the depreciation fund for the electric plant as the life of the electrical apparatus was relatively short, but interest was allowed at two percent on the depreciation fund of the gas plant, which has a much longer life.

This depreciation fund is an important matter, for if no such yearly allowance is made, there will be a time some years after the beginning of operation, and yet before any heavy renewals have to be made, when the depreciation fund should be large, and if no fund has been set aside this amount will either have been put in the surplus or paid out in dividends, either of

which will give a false impression of the status of the company, and later, when the heavy replacements are due, more capital will have to be raised. This is especially important in the sale or purchase of such a property at this particular period of its existence.

GOING VALUE

It was earnestly maintained by the Madison Company that the commission should allow a considerable sum for the "going value" or "good will" of the company. It was reasoned that a company which had been organized, constructed and was in actual operation with a load was worth more than the mere aggregation of materials, land, etc. The expense of getting a plant to such a condition, the loss of interest, the expenses of getting new business, the cultivation of the consumers, and the good will of the public, the rights to do business, which at another time might be refused on as favorable terms, the possession of land conveniently located for extensions, the possession of an efficient working organization and other features were claimed by the company to represent valuable assets and to be properly capitalized at some figure. Various figures were suggested ranging as high as one-third of the valuation of the company. The commission ruled that while these features were undoubtedly valuable to the company, and that such as represented actual expense should be cared for by charging this expense to the proper account, which would be permitted, that no such special efficiency or unusual organization existed in this case as would justify any capital allowance above the actual expenditures required to bring them about. It was further held that as the special privileges and franchises were granted by the community merely that it might be served with electricity, it would not be fair to give these privileges themselves a capital value for rate-making purposes, which would result in making the public pay more for their service.

This matter of going value has been the subject of much controversy, and it is often considered a hardship by plant owners if they are not allowed something for the going value of their system. It is undoubtedly true that in private sales this value is sometimes recognized as of considerable magnitude.

REASONABLE RATES

The next question considered is, What constitutes a maximum reasonable return on the capitalization allowed? The commission concluded that a fair interest rate should be granted on the capital and also a profit or risk rate above the interest, partly on account

of the chance that, through some new discoveries or improvements in the art or unexpected competition, the earning power of the plant might be modified. This risk was not considered very great in this particular plant, but was still appreciable. Again, the commission properly says that as money can earn in other lines of effort more than the usual interest rate, it will not go to public service companies unless it is permitted more than mere interest. They arrived at a value of six percent as a fair interest rate, since the well secured bonds of the company sold on about this basis on the open market. It seemed also to be about the right relation to bonds of other character in the general market. The allowance for profit and risk was two percent, making eight percent in all.

Determination of Rates—It is now an easy matter to determine the maximum reasonable returns allowable for the Madison company at the time of the adjudication, viz., eight percent of $947 000, or $75 760 per year. There remains the specification of rates that may be expected to bring in this income and which will at the same time distribute the burden equitably between the different consumers.

The commission has endeavored to arrive at the rates for different classes of service, on the theory that each customer shall pay a portion of the total gross income of the company proportional to the amount of the total cost that is due to his load. And, more specifically, each customer should pay his share of the fixed or demand costs and of the cost of current generated. As it is manifestly impracticable to consider each consumer, a compromise is made by making all consumers of any class pay at the same rate, that is, contribute at the same rate to demand charges and the same rate for current. This means that those using the current the largest number of hours shall have the current at a lesser total rate which properly corresponds to the lesser cost of producing such long hour service.

To arrive at a knowledge of the cost actually due to the individual classes of consumers, it was necessary to analyze the operating income, expenses and distribution of current very carefully. This the commission did. The apportionment of the actual expenses among the different classes involves many difficult points and some arbitrary assignment so that different tribunals would undoubtedly arrive at different numerical results.

The costs including interest, profits, depreciation, etc. due to the incandescent distribution lines, transformers, meters, etc., clearly were chargeable to the incandescent consumers and similarly with

the other classes of service; but when the costs due to the station are considered, the problem is not the same, for if these costs are divided in proportion to the total number of kilowatt-hours furnished to each class of customers, the lighting which is used for relatively short hours and which is relatively expensive to supply, will not be given its fair portion of the charges. On the other hand, if the total cost be distributed in proportion to the number of lamps actually connected to the line, the incandescent class will be too heavily taxed, as a much smaller proportion of the connected lamps are used at any one time than is the case with some of the other classes. Since the real effect of the different classes of consumers on the station cost is determined principally by their current requirements at the time of maximum demand, that is, at the peak, the commission has apportioned that part of the cost depending on the maximum output of the station in proportion to the relative demands on the station of the several classes of service at this time.

Thus, there is a considerable portion of the fixed expenses that can be definitely apportioned between the classes of service on one logical basis or another, but there still remain other fixed expenses that are not easily so apportioned; for example, taxes and general administrating expenses. These were apportioned arbitrarily between the several classes in proportion to the sum of all the other expenses which had already been apportioned to each.

In making the above apportionment of station capacity demand costs according to the actual proportionate demand of the several classes on the station at the peak, it was necessary to determine how this demand varied with the amount of connected load with different classes, and this was the subject of a good deal of study, but as the methods were rather intricate, it will not be well to describe them here. The percentage of active load, as this relation of the demand of any class at the time of the peak to the connected load of this class is called, varied from 50 percent for residence lighting and some forms of power to 100 percent in sign lighting.

There remain the costs that were proportional to and occasioned directly by the number of kilowatt-hours actually generated. These costs were apportioned according to the actual number of kilowatt-hours utilized by each class of service. Thus to summarize:—

All costs, including the interest and profit on the investment, were grouped into two parts, one proportionate to the demand or maximum output of the system, and the other dependent on the actual use of current. These costs were then apportioned among the several classes of service in proportion to the expense due to

the various classes of service. In this apportionment the direct demand or fixed expenses were charged to the separate classes in proportion as they were caused by these classes, and the output expenses, that is, cost peculiar to the direct production of power, in proportion to the power used by each service. With these total costs and the total number of active lamp months, and the kilowatt-hours used by each class it was easy to determine both the fixed charge and output charge per lamp month for lighting. By active lamp hours is represented the actual proportion of lamps which are in service at one time, multiplied by the average hours monthly use. The various values found for 1908 were:—

Per incandescent lamp month, demand cost. . 12.55 cents
Per kilowatt-hour, for incandescent lamps . . . 4.89 cents

To apportion the revenue from different consumers in the proportion of their appropriate various costs as pointed out, the following series of charges was specified. The schedule was arrived at by calculating, from the data already obtained, the actual cost of power for consumers of a given class using current different numbers of hours per day. This rate must then be secured for such consumers.

RATES SPECIFIED BY COMMISSION

Incandescent Lighting Service—(Classes A, B, C. Residences and business, including incidental heating or power connected on same meters.)—Primary Rate—14 cents net per kilowatt-hour for current equivalent to or less than 30 hours use per month of active connected load.

Secondary Rate—8.5 cents net per kilowatt-hour for additional current used equivalent to or less than the next 60 hours use per month of active connected load.

Excess Rate—Five cents per kilowatt-hour for additional current used in excess of the above ninety hours use per month.

Minimum Bill—$1.00 per month.

Different percentages of the actual connected load are specified for different classes of service as constituting the "active" load called for in the above rates, these percentages ranging from 30 to 100 percent for different classes of lighting.

Commercial Power Service, (direct current)—Fifty cents net per active horse-power capacity per month, plus four cents per kilowatt-hour.

"Active" horse-power is fixed at a certain percentage of the nominal horse-power rating of the motor as indicated on the manu-

facturer's name plate. This percentage varies from 50 to 90 percent by a sliding scale according to capacity, the higher percentage of active horse-power being in the smaller motor. Minimum bill, $1.50 per month.

Certain rates were specified for gas also.

Prevailing contracts made prior to April 1st, 1907, a definite day set by the Public Service Law, were exempt from the prescribed rates.

These rates have a number of advantages as to form and the commission was particular to state that the form of the rates should be carefully adapted to the situation in hand. For example, with the form actually used it is not possible for one consumer by using just enough current to pass a division line between rates to secure a greater amount of current for less total cost than his neighbor, who happens to use just enough less current to remain in the class with the higher rate per kilowatt-hour. Again, generous use of current is encouraged, as the rate falls rapidly with the increasing number of hours use of the installation.

The form of rate is further quite simple and easily understood. On the other hand, some serious objections can be urged against it, and the outcome will be watched with considerable interest.

Finally, to be as certain as possible that no injustice was being done the company, a detailed estimate was made of the probable total income under the new rates, which, while showing less than the actual income, was found to apparently somewhat exceed the allowed value. To be fair to the company, under the requirements of the Public Service Law, however, the commission gave the company the benefit of the difference.

The above analysis of this very interesting and important case is far from complete, but will perhaps serve to give an adequate idea of the principles involved and the method of procedure and to show the actual difficulty in the specification of "reasonable" rates in such cases.

PROTECTION OF ELECTRICAL EQUIPMENT*

PROTECTION OF APPARATUS AND TRANSMISSION LINES FROM THE DANGER OF BREAKDOWN DUE TO ELECTRICAL SURGES

P. M LINCOLN

[This is the second of a series of articles on the general subject of continuity of service in transmission systems, dealing particularly with line stresses and static troubles, and the proper protection of transmission systems from such troubles.]

THE most frequent and severe source of electrical surges is lightning. There are other causes, arising from the operation of a transmission line and the electrical apparatus that goes with it to make up a complete plant. For instance, switching, particularly on the high-tension side, may give rise to surges; also grounding of a high-tension transmission line, particularly if the ground be an arcing one such, for instance, as would occur when the limb of a green tree comes occasionally into contact with one of the conductors of the line. Also a short-circuit on the transmission line or other electrical apparatus may give rise to an electrical surge.

The particular question to be discussed in this paper is, therefore, the manner in which such surges may arise and the best protection to supply in order to prevent them from damaging either the apparatus or service. This discussion is not expected to bring out anything new, but simply to bring a new viewpoint to some who are interested in long distance power transmission and the protection of transmission circuits from damage and interruption.

What is meant by the term "surge"? This is a fair question and should have a straightforward answer. If this question were to be asked of a Steinmetz he would fill pages with differential equations and long "S" signs of integration and finally give an answer, (as he has already done) in the form of a mathematical formula. Such an answer, although it tells the story, is unfortunately useless to the mind of the average long distance transmission line operator since it requires the mind of a trained mathematician to interpret such an answer as well as to make it.

A proper conception of the phenomenon of electrical surges can

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*From a paper read before a joint meeting of the American Institute of Electrical Engineers and the Northwest Electric Light and Power Association, Seattle, Wash., September, 1909.

perhaps be much better conveyed to the mind by using an analogy. The use of a proper analogy conveys a concrete idea rather than an abstract one, and the mind can much more readily grasp the idea in that shape than when it is merely an abstract one which must be always associated with such electrical terms as volts, ohms, henrys, microfarads, etc. Any analogy must be used carefully, since in many points of comparison it is apt to fail. If improperly used, it may lead to conclusions entirely wrong but if properly applied it will lead the average mind to a much clearer conception of what is going on than can be obtained by any consideration of merely abstract quantities.

The following hydraulic analogy is similar in many respects to the electric circuit and its description will doubtless be of assistance to some in gaining an idea of an electrical surge.

Suppose a three-phase, alternating-current generator, trans-

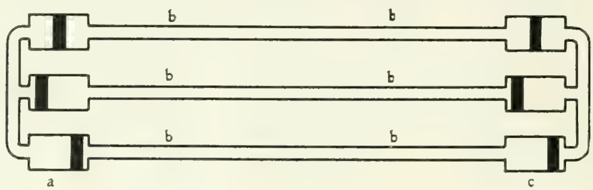


FIG. 1

mission line and receiving apparatus be replaced with an hydraulic arrangement as shown in Fig. 1. In this figure, *a* is the piston pump with the three pistons 120 degrees apart; *c* is a duplicate of pump *a*, whereby the work done by *a* is transferred to *c*, and *bb* are pipes connecting *a* with *c*. The likeness to an alternating-current transmission system is accentuated in the analogy by the fact that the water or other liquid in the system simply oscillates back and forth through the pipes *b* from the generator pump *a* to motor pump *c*. In order to endow this hydraulic system with the functions of an electric circuit it will have to be imagined that the walls of the pipes *b* are perfectly flexible—for instance, assume them to be made of pure India rubber. This introduces into the hydraulic system the analogy of static capacity in the electric system. Also, in this hydraulic analogy the weight or inertia of the water introduced into the hydraulic system is the equivalent of inductance or reactance in the electric system. Since the water in passing back and forth will have certain losses due to friction against the walls of the pipe and pumps, the idea of ohmic resistance of the electric circuit is transferred to the hydraulic analogy.

The effect of increasing the static capacity may be understood in the hydraulic analogy by imagining the walls of the pipe to become more flexible; for instance, to be made of thinner walls of rubber. For a transmission line without capacity it would be necessary to substitute a hydraulic system with perfectly rigid and inflexible pipes. Increased inductance or reactance may be represented in the analogy by increasing the weight and therefore the inertia of the liquid pumped; for instance by substituting mercury for water. Increase of electrical resistance may be represented by smaller, rougher or longer pipes, thus increasing the frictional resistance. It is further necessary to assume that the volume of the pump cylinders is large compared with the volume of the pipes connecting the two pumps, and to gain a proper idea it would be necessary to imagine further that the speed of the pumps is slow, say one stroke per minute or so.

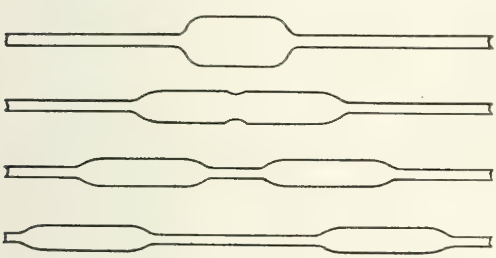


FIG. 2

The nature of an electric surge may now be investigated by means of this analogy. Suppose that an amount of liquid be suddenly injected into one of the flexible pipes b at some point betwen pumps a and c sufficient to swell the pipe at that point instantly to some three or four times its normal diameter for a length of some eight or ten diameters. This would be analogous in the electric system to the effect of lightning. In this case, a cloud discharges in the neighborhood of a high-tension transmission line. The area of the transmission line which has been covered by the cloud is relatively small. The discharge of this cloud releases a certain amount of static electricity in the transmission line in addition to the normal amount of current present due to the action of the generators and receiving apparatus. What happens next? It is much easier for the imagination to follow this in the analogy than in the actual transmission line. If the pipe is not strong enough the wall breaks—that is, an insulator punctures or "slops over"—and the accumulation of water—electricity—in part, at least, escapes. If the walls of the pipe are strong enough to stand the strain—that is if the insulators do not break down—a wave or

surge begins to be propagated in both directions. The distended walls of the pipe bring their elastic force to bear upon the enclosed liquid and the accumulated "lump" of water begins to be dissipated in both directions. The inertia of the liquid together with the pressure on it from the elastic walls will cause it to assume successive forms which are probably very much like those shown in Fig. 2. The accumulation of liquid will become longer and thinner and it will finally divide into two separate "lumps" as it travels from the point of disturbance in both directions. At the point of disturbance the tendency to break the walls is a maximum and this tendency becomes less and less as the wave or surge proceeds from the point of disturbance. However, should the surge encounter a weak place in the walls, a break might occur in some place comparatively remote from the point of disturbance.

In considering what happens when this wave or surge reaches the electrical apparatus at the ends of the line it will be necessary, for the purpose of further analogy, to replace the pumps with something that will behave like a transformer or generator in an electric system. Now, generator and transformer windings have two important differences from an equal length of transmission line in that both the capacity and inductance per unit length are largely increased. Accordingly, in the hydraulic analogy the increase in capacity per unit length may be represented by imagining a much thinner walled pipe for the generator. The increase in inductance per unit length may be represented in the analogy by an increase in the specific gravity of the liquid—say by substituting mercury for water. An endeavor has been made to give a graphic representation of these modifications in Fig. 3, in which B_1 is the transmission line with relatively heavy walls although still flexible and with a light liquid contained therein, say water; and B_2 is the generator which has relatively thin but still perfectly elastic walls containing a heavy liquid, say mercury.

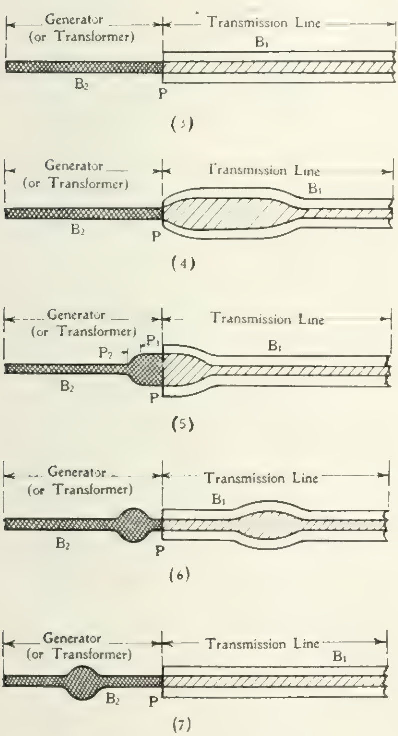
When the wave or surge that has started out on the line B_1 reaches the point P, that is the terminal of the generator or transformer, it is obvious that the following things must occur:—

First—A part of the energy of the incoming wave will be reflected and will therefore travel back through the line B_1 from the point P.

Second—The remainder will begin to travel through part B_2, the generator or transformer, but the speed of its propagation will be very much reduced because the liquid being set into motion is

very much heavier and also because the forces acting upon it through the elastic retaining walls are much smaller.

Third—The steepness of the wave front during its propagation through B_2 will be very much increased over that obtaining in B_1 on account of the action of the same forces as noted above.



FIGS. 3, 4, 5, 6 AND 7

Figs. 4, 5, 6 and 7 give the writer's idea of how the wave will modify itself when being propagated from medium B_1 into medium B_2. Probably the most noteworthy modifications during the transfer of the disturbance from B_1 to B_2 is the abrupt increase in the steepness of the wave front. For instance, consider the points P_1 and P_2 in Fig. 5. At P_1 there is a tendency to burst the pipe, that is, to break down the insulation to ground; but there is also a heavy stress tending to break through, from point P_1 to point P_2. Suppose that the portion B_2 of the pipe, instead of being straight, as indicated in the diagram, were to be coiled upon itself, there being one complete coil between P_1 and P_2; then there would be a tendency for the liquid at point P_1 to break through the walls of the pipe into the neighboring coil at P_2. This is exactly what occurs in the electric system. An incoming surge, in penetrating the turns of the electrical apparatus, causes an excessive voltage strain between adjacent turns. The momentary breakdown or snapping across of this surge from one turn to the next will do no particular damage unless this breakdown is followed by the dynamo current and an arc is thereby established. In case the latter occurs, the break is liable to do great damage. In the writer's opinion, practically all of the failures in generators, transformers, etc., which can be traced directly to lightning or other surges, are due to a breakdown between turns

rather than to a break of the insulation from conductor to the ground. There is of course, due to the normal operation of the apparatus, an insulation strain from conductor to ground and also one between adjacent turns. A surge momentarily increases both of these strains. The strain to ground may thereby be increased 20 percent, 50 percent, perhaps 100 percent, or even somewhat more; and the strain between turns may be increased 20, 50 or 100 times or even more. A surge therefore throws a tremendously larger increase of strain on the insulation between turns than it does on the insulation to ground. From certain observations that the writer has made, it is his opinion that the momentary strains between turns, particularly near the terminals of the apparatus may approximate a considerable percentage of the terminal pressure. This is a danger in electrical apparatus which has not been sufficiently appreciated in the past.

It is evident that the protection of electrical apparatus from such dangers as are outlined in the above consists in:—

1—Making the apparatus so that it will stand large momentary voltages between turns. This consideration shows the great advantage possessed by transformers, particularly the oil-insulated types, over generators, as it is possible to insulate transformers between turns to a much higher degree than any generator can be.

2—Limiting by use of proper lightning arresters the size of the wave or surge that may enter the electrical apparatus. Reverting to the hydraulic analogy, if a hydraulic relief valve were provided at the point *P*, Fig. 5, it would have the effect of removing at least a part of the excess liquid at the instant the strong pressure on the walls occurs. If this relief valve were to be set at a pressure of say only 20 to 30 percent above that caused by the pumps while in normal operation, then this relief valve would not affect normal operation and would also limit a surge or wave entering the part B_2 to an amount which could not exceed 20 or 30 percent above normal pressure or voltage. This indicates the function of the ideal lightning arrester. It prevents any electrical surge which has a value 20 to 30 percent greater than the normal voltage from entering the electrical apparatus. This is the utmost that any lightning arrester can do. The electrical apparatus itself must be so designed that it will take care of an entering surge which is not more than 20 or 30 percent above line voltage.

Reverting again to the hydraulic analogy, suppose the relief valve has a relatively long discharge pipe of say 1/100th the area

of the incoming pipe *b* in Fig. 1. The time during which the excess pressure exists at *P*, Fig. 5, is relatively small. Such a pipe attached to the relief valve would be utterly unable to discharge a sufficient amount of the liquid to relieve the pressure. As a consequence the size of the surge entering part B_2 would be but little reduced by such a relief valve. This is analogous to what occurs with a lightning arrester having a large ohmic resistance in series with it for the purpose of preventing the dynamo current from following. This indicates in general why this type of arrester is inferior to the electrolytic. The electrolytic type of arrester, once broken down, has almost a zero resistance to ground and therefore allows the maximum possible reduction of the surge before it enters the electrical apparatus.

Another method of protection that has shown itself of considerable value, both in theory and practice, as a protection from lightning is the overhead grounded guard wire. The theory of this kind of protection is as follows:—

Any conductor that is entirely enclosed or surrounded by another conductor cannot have induced thereon a static charge which originates from any action going on outside the surrounding conducior. For instance, a lead covered electric cable cannot be directly subjected to lightning disturbances because of the protective action of the surrounding lead sheathing. The overhead ground wire acts to a certain extent in the same manner. Although it does not entirely surround or enclose the high-tension wires which it protects, it does so partially, and to this extent, at least, it provides the same protection as does the lead sheath to the underground cable. In the electric transmission circuit the voltage of the charge which would otherwise be induced upon the transmission line is kept down by the presence of the grounded guard wire.

Still another method of protecting high-tension transmission lines is to ground the neutral of the lines. This grounding may be done either by connecting it solidly to the ground or by putting in a greater or less resistance between the neutral point and the ground. To just what extent this grounding of the neutral, either completely or partially, is of value, is a mooted question among engineers. In the opinion of the writer, the question of grounded versus ungrounded neutral may be considered from two view points; first, from the viewpoint of protection of the appara-

tus or equipment, and, second, from that of the protection of the service.

1—Protection to apparatus. The advantage in a solidly grounded neutral, so far as protection to apparatus is concerned, is that the normal voltage to ground can under no conditions rise to more than about 58 percent of the normal voltage between conductors. This advantage is, of course, of the utmost importance when considering insulation strengths to ground of the various apparatus involved. On the other hand, the disadvantage of a solidly grounded neutral is that every ground which occurs develops immediately into a short-circuit and these short-circuits in turn cause severe mechanical stresses to be set up in the transformers and the generating apparatus.

With a grounded neutral, therefore, it is reasonable to expect that the windings of the transformers and generators will be subjected to much more frequent shocks than without such a ground. Also, owing to the fact that every ground immediately becomes a short-circuit and that at points of short-circuit the arc will cause considerable destruction, the system with the solidly grounded neutral will be subject to more frequent destructive arcs, both on the line and in the apparatus where there is probability of such arcs developing.

So far as protection to apparatus is concerned, it is the writer's opinion that the advantages of grounding the neutral very much outweigh the disadvantages and, if protection to apparatus alone were to be considered, he would have no hesitation in making recommendation for a solidly grounded neutral.

2—Protection to the service. As mentioned above, the disadvantage of a solidly grounded neutral is that every ground develops immediately into a short-circuit. With a voltage such as is always used in high-tension transmission (say 44 000 and above), there will always be a sufficient voltage at the point of arc to cause that arc to continue until power to that particular section of the line is cut off. This fact will almost invariably cause an interruption of power whenever a ground occurs on any point on the transmission system.

This would not be of such material disadvantage were it not for the fact that experience has again and again demonstrated that lightning storms will very often cause insulators on the line to arc across or puncture. With the neutral solidly connected

to ground each one of these punctures and flash-overs means an interruption of service. If the line were not solidly grounded it is probable that many of these flash-overs would not interrupt the service, since a flash-over involving only one conductor might simply mean that the other two conductors on the transmission line would momentarily rise to a potential nearly double normal, while the arc at the defective insulator, as well as the voltage to maintain the arc, would disappear.

In view of the difficulties which the line is apt to encounter with a solidly grounded neutral, many engineers prefer to ground through a resistance instead of connecting the neutral solidly to ground. In order to be of use, the resistance between the neutral and ground must be relatively high, and it further must be able to carry a considerable current for at least a short period of time. In other words, it must be capable of dissipating a very considerable amount of energy for a short period. A satisfactory type of resistance for this grounding service is difficult to secure. Cement columns have been used, but these are unsatisfactory owing to the extreme variability of their resistance. Also if the current through them is maintained for an appreciable time the heat developed is apt to crack or even to burst them. After studying the question from various view-points the writer has come to the opinion that a metallic form of resistance is the proper one to use for this purpose. The main disadvantage of this form is its cost, but its advantages are sufficiently great to overcome this objection.

To recapitulate briefly the protection against surges of electrical equipment, including both the apparatus and transmission lines, may be furthered by adopting some or all of the following methods:—

1—The overhead grounded guard wire. This keeps down the quantity of electricity which a given lightning discharge is capable of superposing upon a transmission line. In practice it has shown itself to be a valuable device in many instances of high-tension transmission.

2—The use of efficient lightning arresters is essential. They should be of a type which will allow a free discharge of static electricity from the transmission line whenever the voltage of the charge exceeds normal by a certain predeterminable amount. With a proper equipment of such lightning arresters the size of the surge which may enter electrical apparatus is limited.

3—The grounded neutral. Grounding solidly prevents the potential of a neutral point of a transmission line from departing from ground potential. This in turn prevents the normal operation of this line from causing more than about 58 percent of line voltage to appear between any conductor and ground. Grounding through a resistance has the same effect, to an extent dependent upon the amount of resistance used.

4—Insulation between turns. The analysis in the preceding discussion shows that it is highly essential to insulate electrical apparatus between turns so that it will stand a momentary potential which is many times that normally put upon the insulation. The consideration of this point shows at once the enormous advantage of using transformers upon a transmission line instead of connecting the generators direct. The amount of insulation that can be used between turns in a generator is limited by the necessity of placing the winding in relatively small slots. In a transformer this consideration does not operate to nearly so great a degree owing to the fact that the space occupied by the windings is, so to speak, in one piece instead of being divided up into a large multiplicity of small slots. Also the presence of oil in the case of the transformer gives it an advantage which the generator cannot have under any conditions.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

456—Standardization Rules of A. I. E. E.—Where can I obtain a copy of the Stardardization Rules of the A. I. E. E., and what is the price per copy? B. L.

The American Institute of Electrical Engineers advertise in the monthly "Proceedings" copies of the Standardization Rules at ten cents for the paper edition, and twenty-five cents for the cloth edition. These can be obtained by addressing the secretary, Mr. Ralph W. Pope, 33 West 39th street, New York City.

457—Over-Heating of Squirrel-Cage Induction Motor—A new three-phase, squirrel-cage induction motor was run for a short time with load and developed a hot bearing. The bearing was repaired and when the motor was again started it refused to speed up. However, by pulling on the belt, it was caused to speed up and to pull into step. On reaching full speed the rotor became so over-heated that the solder at the points where the bars are connected to the end rings was melted away. The load was then thrown off, whereupon the motor quickly came up to speed. After re-soldering and replacing the rotor, the motor would not run on normal voltage, but required a considerably higher voltage to start. The old rotor was then replaced by a new one without effecting a remedy. Please give the cause of this apparent weakening of the starting torque. Could it be due to the heating of the rotor teeth, resulting in an increase in the reluctance of the stator magnetic circuit? What will restore the motor to normal condition? M. H. S.

The trouble is due either to wrong connections or excessive starting torque. The connections should be carefully checked to make sure that the motor is not being started on one phase only. The excessive starting torque could be due either to too great load or to too great belt tension. There is no ground for the suggestion regarding the rotor tooth heating, as the iron might be heated to redness and cooled again without seriously impairing its permeability. Try slacking off the belt. If a high belt tension was required, due to short distance between pulley centers, increase the distance between centers or use an idler pully, so as to increase the angle of contact of the belt on the motor pulley. A. M. D.

458—Calculation of Percentage Error of Wattmeter—In testing a 110 volt, five ampere, single-phase service wattmeter with a portable standard integrating wattmeter, while the service meter makes 30 revolutions the standard meter should make 27 revolutions; however, the latter actually makes 29.7 revolutions. Which of the following methods is correct for calculating the percentage error of the service meter:—$(29.7 - 27) \div 29.7 \times 100 = 9.09$; i.e., the service meter is 9.09 percent slow, or $(29.7 - 27) \div 27 \times 100 = 10$; i.e., the service meter is ten percent slow. The error introduced by using the wrong method of calculation might, of course, be greater with different conditions. J. L. S.

The first method is correct. It may be checked by assuming a meter to be running at say twice the correct speed (i.e., by increasing the discrepancy), when its correctness will be evident. W. B.

459—Parallel Operation of Three-Wire, Direct-Current Machines—A three-wire direct-current generator of the design employing choke coils connected

through collector rings to armature taps is being operated at present in our power plant. To obtain additional capacity we propose the installation of another three-wire outfit to be operated in parallel with it, the latter to consist of a two-wire generator and a motor-generator balancer set. The two-wire generator and balancer set would be connected in parallel across the outside mains of the present three-wire circuit, the neutral point of the balancer, i. e., the common connection of the two units composing the set, being joined to the middle wire of the three-wire circuit. The purpose of this proposed paralleling of the two types of three-wire generator sets is to avoid the heavy cables which would otherwise have to be provided as equalizer connections in case two similar machines of the type installed at present were operated in parallel, in this way to simplify the switchboard connections. L. G. M.

These two equipments will operate in parallel with proper division of main and unbalanced load if the characteristics of the two-wire generator and of the balancer set are adapted to the characteristics of the present machine. The function of the motor-generator balancer set is to maintain approximate equality of voltages on the two sides of the neutral wire regardless of the load distribution. This is accomplished through the motor-generator action of the set, the machine on the more heavily loaded side of the neutral operating as generator driven by the other as motor; the current of both units combining, supply to the heavily loaded side of the system the required neutral or unbalanced current at the voltage of the generator unit. The set is inherently reversible and automatically adjusts itself to the shifting of the unbalanced load. The balancer set should have the same voltage characteristics as the balancing characteristics of the three-wire generator; i.e., when each is carrying its rated proportion of unbalanced load, the voltage unbalance should be the same in each. The balancing characteristics of the three-wire type of generator are inherently drooping (i.e., shunt characteristics) and require a shunt wound motor-generator balancer set for parallel operation with it, (a motor-generator balancer set with compound characteristics would assume practically all of the unbalanced component of the load). This would call for a low resistance armature in the balancer, which in turn would usually necessitate special design or under-rating of standard apparatus. Moreover, if the three-wire generator at present in service is compound-wound any additional two-wire or three-wire generator capacity would have to be compound-wound, in which case equalizer connections would have to be provided. A. C. L.

460—Removal of Deposit from Transformer Cooling Coils—In a 100 kw, oil-insulated, water-cooled transformer the cooling coils have gradually become clogged with a deposit, until they will now pass but little water. What is the best way to clean them? Can they be cleaned without removing them from the transformer tank? F. S. P.

This is an unusual occurrence in transformer practice and would indicate that the water used for cooling purposes has a comparatively large percent of solid matter, in solution or suspension, the action of the heat being to deposit it on the interior of the cooling coils. The only method that we can suggest for the removal of this deposit is by chemical means. An acid may be used, but this would endanger the metal itself. The only intelligent way of determining the proper chemicals to use would be to obtain an analysis of the water causing the trouble. Thus the exact nature of the deposits and the percentage in which they occur in the water may be definitely determined, after which the exact chemical treatment necessary for their removal could be indicated. See "An Incident with Water-

Cooled Transformers," in the JOURNAL for Oct., '05, p. 600.

461—Synchronizing Voltmeter—In connecting a 500 hp, three-phase synchronous motor to a 3000 volt, three-phase circuit, what method may be used to prove that the synchronizing voltmeter is correctly connected, i.e., that when reading double voltage, the phases of both machine and line are in phase? The machine is started by means of an induction motor mounted on the same shaft. G. F. B.

A synchronizing voltmeter consists of two distinct windings which are so arranged that their action on the indicating needle will be opposed each to the other. One of these windings is connected to the running circuit, the other to the incoming circuit. The instrument simply serves to indicate when the voltage of the incoming machine and that of the circuit with which it is being connected are at equal potential. Accordingly, the action of the instrument is independent of the phase relations and relative frequencies of the two circuits. See Nos. 157 and 256, also p. 20 of the Six Year Topical Index of the JOURNAL, for further information regarding synchronizing. H. W. B.

462—Aluminum Electrolytic Rectifier—Please describe the general construction of the aluminum electrolytic rectifier as regards plates, chemicals, etc. Has any metal been found that would be superior for use as an electrode? J. M. C.

Information regarding these properties is given in questions and answers referred to in the Six Year Topical Index, p. 15. Aluminum is the only metal that is commercially used; its resistance, in a solution, to current flowing from the metal to the solution is much greater than when the current is flowing in the opposite direction. Many metals manifest this property of asymmetrical resistance in solution to a varying extent, but only aluminum and some rare metals (including tungsten) have the property to such an extent that they will rectify alternating current at commercial voltages. L. W. C.

463—Effect of Alternating-Current Field on Inductor Alternator—Can a Warren inductor generator be made to generate power if the field is excited with alternating-current of about the same frequency as that at which the machine is operated? A. S. MCC.

The effect of applying alternating-current to the field winding for purpose of excitation would be to set up eddy currents in the iron of both the stator and rotor. This is natural to expect since the frequency in the stator would be increased above normal while that in the rotor would be changed from zero to the exciting frequency. Since certain parts of this type of machine are not laminated the additional heating would probably be prohibitive.

464—Superior Efficiency of Tungsten Lamp—Is the superior efficiency of the tungsten lamp over the carbon due to the higher temperature of the former filament or to certain properties of selective radiation or emissivity, resulting in a larger proportion of the radiated energy being of wave lengths within the visible octave? O. H. C.

The temperature of the filament in the carbon lamp burning at 3.5 watts per candle is approximately 1800 degrees C. The temperature of the tungsten filament burning at 1.25 watts per candle is in the neighborhood of 2300 degrees C. The higher efficiency of the tungsten lamp is due primarily to the higher temperature of the filament. This is explained in "The Problem of Efficiency in Illumination" in the JOURNAL for March, 1909, pp. 165-6. It is, as yet, an open question whether the tungsten lamp exhibits the phenomenon of selective radiation. Several good authorities consider that it does show selective radiation. The high efficiency of the tungsten lamp is not, however, due to this quality. A. J. S.

465—Economical Voltage for Transmission Circuit—Power to the amount of about 250 horse-

power is to be transmitted a distance of 2500 feet. A 460 to 480 volt, 60 cycle, three-phase circuit is available as a source of power. Which would be economical; to transmit at this voltage or to raise the voltage to about 2200 volts by means of transformers at the source of power and then down again to 440 volts at the motors? H. W. F.

Assuming that it would be impossible to employ high voltage motors, thus eliminating transformers at the load end of the circuit, it will be found that the initial cost of the transformers which would be required at the generator end of the circuit for stepping up the voltage would be nearly as great as that of the copper required for operating at 460 to 480 volts, allowing for a drop in voltage of ten percent due to line loss. Thus, the lower voltage would be more economical from the standpoint of first cost. The use of the higher transmitting voltage would involve, in addition to the transformers, the cost of line copper, increased cost for insulators and line construction and a possible additional cost for step-down transformers in case it would not be possible to use motors suitable for operation at the higher transmission voltage of the line. On the other hand the use of 2200 volts would cause less loss and the final choice would depend on the value of this lost power. P. M. L.

466—Type of Induction Motor Suitable for Operation of Air Compressor — Which is better suited to the operation of an air compressor, a squirrel cage type or a wound secondary type of induction motor? The load is about ten horse-power. The compressor is operated in connection with an automatic unloading device and the motor is controlled by means of an automatic starter. The maximum and minimum pressures are 100 and 70 lbs. respectively. C. R. E.

Air compressors have high starting friction because of their construction and number of parts. The constant speed type of induction motor having phase-wound secondary is, therefore, most suitable for this kind of load. Information covering this question is given in article by Mr. A. M. Dudley, in the JOURNAL for July, 1908. For further information regarding motor applications, see the Six Year Topical Index, pp. 22 and 23.

467—Effect of Over Speed on Operation of Alternating-Current System—A measurement of speed of the generator of a local alternating-current power and lighting system revealed the fact that the 60 kw, 1100 volt, 60 cycle, two-phase generator has been operating at a speed of 1100 r.p.m., whereas its rated normal speed is 900 r.p.m. How does this increase in speed effect the performance of the generator as regards voltage, capacity, and life? How does it effect the frequency of the circuit? How does it effect the meters, transformers and motors? J. K.

If the field current of the generator were maintained at the same value when operating at 1100 r.p.m. as when operating at 900 r.p.m. the voltage would be increased in proportion to the increase in speed. It is probable, however, that the field current has been reduced by the introduction of resistance in the field circuit, thus giving the normal operating voltage. On the latter assumption, the increase in speed would have the effect of slightly increasing the capacity of the generator due to the greater ventilation produced. The frequency is proportional to the speed. The effect of increased frequency on the transformers is to reduce their iron loss and thus increase their efficiency and capacity. The motors will also operate at a somewhat reduced iron loss and slightly better efficiency; their speed will be proportional to the frequency. Meters of modern design are but slightly affected as regards accuracy of registration at an increase of voltage of 25 percent. (See No. 419). The only probable effect on the life of the generator and motors would be a possible increase of wear and tear due to the higher operating speed. P. M. L.

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Electricity in the Lumbering Industry in the Northwest

Eight years ago it was exceedingly difficult, and in fact almost impossible, to interest lumbermen in the use of electric power. As a matter of course, every sawmill and nearly every shingle mill had its electric light plant, because the incandescent lamp for mill lighting and the arc lamp for yard lighting appealed to millmen as adequate, safe and inexpensive. Oil lamps were a serious fire risk and furnished very poor light. However, when it came to considering the next logical step in the use of electricity; i. e., its application as a motive power, several things stood in the way of any rapidity of progress.

First—The use of electric motors in factory work, while having even then a very wide application, had not assumed anything like the very commonplace aspect that came about in a very short time. Those lumbermen who gave any attention to the subject no doubt were preparing themselves for a later day application, but did not feel that the time had come to put a foot forward.

Second—No one had made a start (we refer particularly to the Northwestern states of Oregon, Washington and Idaho) in the use of electric motors in sawmills. Various applications had been made to planing mill work, in every instance with attendant success, but very little information was available as to what size of motor, for instance, would be required to drive a bandsaw, or what results would be obtained from such method of drive. Timidity existed, therefore, in a form called conservatism. "Let the other fellow find out and demonstrate what can be done. If he is successful, then we may take a look for ourselves," is a good exposition of the common attitude then existing.

Third—Steam power was cheap; shaft friction losses, belt losses, large steam engine losses from exhausting into the atmosphere and the consumption of tremendous quantities of fuel in fire heaps were matters of little or no concern. The cause of this

was that mill waste had very little market value as fuel, and no commercial reasons existed why power economy should be sought and maintained.

Since that time these primary and basic obstacles have all vanished. Seemingly they have all been forced out simultaneously by conditions that have automatically come into existence. The pressure of the times has been felt by the mill owners. The fact that practically every belt from a line shaft can advantageously be replaced by an individual drive or group drive motor has been demonstrated by a few hardy pioneers in the business of electrification of sawmills. The additional fact that fuel wood delivered at residences of Seattle, Tacoma, Portland and other Puget Sound cities costs the consumer $6.00 per cord at certain seasons of the year, and never less than $4.00 per cord, and that even higher prices are demanded and obtained in inland towns, is a sufficient and unanswerable argument as to why economy should be practiced in the use of slab-wood, the mill by-product, and why the absolute cessation of the economically sinful practice of dumping it into conveyers feeding mill fire heaps or specially constructed burners, should speedily be effected.

Mill after mill has thus been consuming shameful quantities of good fuel annually, but the fact that certain wide-awake and conservatively disposed mill owners have really stopped this is indeed a hopeful sign. Only a few weeks ago the writer saw enough slab-wood dumped into one of these conveyors in five minutes to heat an average residence for several months. The crime, for such it is, is of the same order as the destruction of a coal deposit, or the deliberate burning of a forest. It should find no place in the order of the day.

Conservation is the present day watchword and, correctly interpreted, has a tremendous bearing upon some of our existing practices. There is a strong and fundamentally sound reason why natural resources should be developed and used in the most economical manner, such that the greatest good will result to the greatest number of people. There is just as little excuse for prodigal use of power as there is for the deforestization of our hills and mountains. In the one case, where exhaust or low pressure steam is ejected into the atmosphere in large quantities, losing a large proportion of the total energy it contains when it leaves the boilers, an absolute waste occurs. If this low pressure steam is used in a turbine, nearly as much power will be delivered at the turbine shaft as is developed

by the high pressure engine, all accomplished without any more fire under the boilers or any larger boiler capacity.

In the other case, deforestization means a less average precipitation, a more uneven run-off, such that streams are more difficult to control and a larger part of the total precipitation is lost in the shape of flood waters than is the case when the forests act as binders of moisture to the soil. There is an exact comparison, therefore, between the two cases; both are wasteful, neither has any of the elements of economy.

Quite a few mills are equipped with high-pressure single-cylinder Corliss engines, operated non-condensing. Frequently the desire to enlarge and to increase output accomplishes the double result of securing such increase and also maximum power economy, by the use of low pressure or mixed pressure turbines direct connected to electric generators. A suitable mixed pressure turbine will use all the exhaust steam previously wasted and at times of shutdown of the reciprocating engine or of unusual peak loads on the power plant, high pressure steam is admitted to the turbine and the extraordinary power demand is met in this manner. One mill, known to the writer, exhausts enough steam at atmospheric pressure to carry a load of 3 000 horse-power if provided with proper turbine equipment. The possibilities of economy are great in this instance.

Another mill owner, who was confronted with the above conditions, purchased a turbine equipment and runs his generators in parallel with the 2 300 volt system of a central station company, to which he sells power at a rate profitable for both parties, besides carrying his own motor load.

That mill owners are taking an active interest in the use of electric power is evident from the fact that between twenty-five and thirty large companies in Oregon, Washington and Idaho have either installed or ordered electrical equipment. Not all of them use low pressure turbines, as conditions in some cases are decidedly in favor of using high pressure or mixed pressure turbines. The amount of attention being given this subject in general by lumber manufacturers is remarkable and in the Pacific Northwest the principal line of activity among electrical manufacturers is in connection with this general movement. A. A. MILLER

An Alert Central Station Policy

The Company Section is a comparatively new feature of the National Electric Light Association which is becoming a very forceful factor in central station development, particularly in the larger companies. A recent meeting of the Brooklyn Company Section made a deep impression upon a guest at the meeting, and, as others may be interested, an account of it will be recorded here.

The meeting was held at one of the summer hotels on Manhattan Beach on the afternoon and evening preceding the annual opening of the hotel. At the evening dinner in the interval between the two sessions there were 370 present, including a dozen guests. Here were over 350 employes of a single central station, voluntary members paying dues in the National Association, and there were still other members who were not present. These men came from all departments of the company.

This section holds evening meetings of business or social character through the winter, concluded by a more pretentious afternoon and evening convention and dinner at the close of the season.

The president, who belongs to the construction department, made an introductory address which would ordinarily take about ten minutes, but he finished in three. Reports and business matters were disposed of in five or ten minutes more and then followed the reading and discussion of papers. The first was Mr. Lupke's notable paper presented at the St. Louis convention of the National Association and printed in brief in a recent issue of the JOURNAL. Other St. Louis papers were read, and there were several original papers dealing with station equipment, distributing systems, office methods, and business getting of the Brooklyn Company. With the exception of one or two papers which were read *in toto* instead of being condensed, the presentation was crisp and interesting. There were usually two or three brief prepared discussions in connection with each paper. The older men joined in at times, but the greater proportion of the discussion was carried on by the young men, some of whom were just beginning their public speaking career. The concise and pointed prepared comments were usually followed by other discussion closed by the man that presented the paper, who often had a number of questions to answer.

I had noted the rather long list of papers, and with the liberal discussion, I anticipated that it would be a long time till dinner.

But after two hours I found we had done nearly a day's work, measured at the rate of some conventions.

In the evening there were more papers and addresses by an invited guest and by President Freeman, of the National Association, who is an officer of the Brooklyn company. His words of counsel, encouragement, and inspiration, and his call for the best efforts of all in advancing the general interests of the company and in making a brighter Brooklyn made a fitting close of the convention, and incidentally suggested the company policy which underlies the success of the Brooklyn Section.

In a large company efficient interaction between departments becomes more difficult as size and numbers increase, and it is the acquaintance and mutual understanding as well as the better knowledge of the methods of other departments which makes such meetings of first importance as a part of the new central station policy. A few years ago it was suggested to the president of a large lighting company that it should advertise. "Why?" he replied, "We have a monopoly; the public must come to us for current if they want it." By the new policy the central station is conducting organized campaigns for new business and, further than merely asking for customers, it is showing the people how to use current, how to do their work better and more economically by using motors, how to be brighter and more cheerful by the proper use of more lamps and fans and cookers. The average citizen has an abiding faith in the mysteries of electricity, but often no practical idea of how it can be made serviceable to his own purposes. He must be shown. And the central station is realizing that it is its business to show him. The first need of an alert company is alert men, and one way to make them so is by the kind of organization which the Brooklyn Company is fostering.

At the present rate of growth, electrical output doubles in five years. A doubled central station load in five years from now will mean much to the central station; it may mean as much in promoting the interests of the community which it serves.

Chas. F. Scott

THE TUNGSTEN LAMP AS A FACTOR IN MODERN STREET LIGHTING

C. E. STEPHENS

THE determination of the intensity of illumination required and the best method of producing this illumination with the minimum cost form the fundamental problems of street lighting. The area to be lighted is a long and comparatively narrow strip. The result desired is approximately uniform intensity of illumination along the street with a somewhat higher intensity at street intersections. The cost involves the energy expended, the maintenance of the lamps, and interest and depreciation for the lamps, plant and all auxiliary equipment.

The intensity of illumination at any point is proportional to the light intensity of the unit and inversely proportional to the square of the distance from the light source. It is evident, therefore, that to secure a given illumination, the energy supplied will vary directly with the separation of the lamps, i. e., if the distance between light sources be doubled, each lamp must have four times the light flux, and the energy required per mile of street will be doubled. If the problem could be solved on an energy basis alone it would be logical to use a maximum number of light units with a corresponding reduction in their light flux and energy consumption. Increasing the number of units, however, also increases the installation and maintenance costs, and a spacing must be selected where the energy saving will balance the cost of the increased number of lamps. A general solution is impossible on account of the numerous variables which are involved, such as the intensity requirements in different sections of a city, obstacles which prevent a proper location and distribution of lamps, energy costs, etc. When considered from the standpoint of economy only, if the cost of energy is low, large units at great distances apart are better, and if the cost of energy is high, small units at more frequent intervals are more economical.

It should be noted that this statement applies only to the illumination of long and comparatively narrow areas, where the area lighted varies directly with the distance between units. It does not apply to the illumination of large areas where the lights are spaced on the basis of the square, since here the area lighted by each unit varies with the square of the distance between units, and the light efficiency is independent of the spacing of the units.

The requirements for good street illumination may be considered under the following heads:—Uniform intensity—distribution; diffusion; intrinsic brilliancy of light source, and shadows.

Uniform intensity of illumination is desirable throughout the length of the street, except at street intersections and other points where traffic is liable to be congested. At these points the intensity can be much greater than that of the minimum illumination and not be objectionable, since at such places no vehicles will approach alternate light and dark spots so fast but that the eye can easily accommodate itself to the different intensities of illumination. For business sections or other sections of a street where a high intensity is maintained, the ratio of maximum to minimum illumination should not exceed ten to one. For residence sections, parks and outlying districts this ratio should not exceed five to one. The ratio of maximum to minimum illumination should be smaller in the latter case because in such sections it is ordinarily quite satisfactory to provide a minimum illumination which is just sufficient for seeing vehicles, persons or possible obstacles in the street, and where the illumination intensities are low, comparatively light and dark spots produce objectionable glares. Furthermore, it is in these sections that fast moving cars, automobiles and carriages are found. Uniformity is therefore of greater importance in the residence or other sections of a city where low intensities of illumination prevail than in the business sections where higher intensities are used.

To produce a uniform intensity a certain distribution curve is required for a given location of light sources. The very nature of the street area determines that the light units must be in a single or double row along the street. The number and size of units are determined by the intensity requirements, and the cost of operation. The height of a lamp is usually limited by the cost of installation, maintenance, tree obstruction, etc. Under these conditions it is desirable to select a lighting unit with a maximum intensity at from 15 to 20 degrees below the horizontal, the intensity decreasing very rapidly above and below this angle.

In any illumination scheme, it is objectionable to have the light flux issue from a point. This is particularly true in street lighting where relatively large units are employed, since it is impracticable to support a lamp at such a height that it will not come within the range of vision at a time when the eye is quite near the lamp. It is not possible to change the nature of the light source, but by an

intelligent use of the glassware available for modern street lighting units it is possible to diffuse the light quite satisfactorily.

The most objectionable features of an improperly diffused light are the high intrinsic brilliancy and the resultant sharpness of the shadows cast by the illuminated objects. The extreme brilliancy causes a contraction of the pupil of the eye and produces the same physiological effect as that produced by a reduced intensity of illumination. Though there is a considerable loss of light by absorption when a diffusing medium is used, the final result will usually be far superior in that a greater proportion of the light flux will be useful. Moreover, the shadows of an object illuminated by direct light are very sharply defined, and in street lighting they are usually quite long. Under these circumstances it is difficult to distinguish clearly the outline of small obstructions, which appear magnified in size. To minimize this effect, the source of light should be thoroughly diffused and should be as high as possible in order to avoid excessively long shadows.

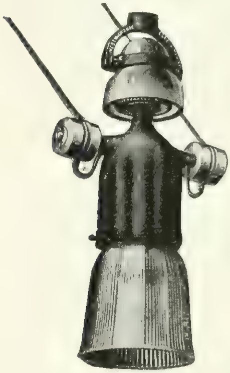


FIG. 1—STREET HOOD EQUIPPED WITH HOLOPHANE STREET LIGHTING REFLECTOR

The general characteristics of a suitable street lighting unit may be briefly reviewed as follows:

1—The maximum intensity of the light unit should be from 15 to 20 degrees below the horizontal, and decrease rapidly above and below this angle.

2—The total light flux from a single unit should be as small as conditions will permit, i. e., for a given intensity of illumination a maximum number of small units spaced at frequent intervals should be used.

3—The light should be diffused, i. e., emitted from a large area.

4—The light should be supported at the maximum permissible height above the illuminated surface, particularly if it is a large unit and the light is not diffused.

There is no doubt but that as a whole the street illumination in American cities is inferior to that of European cities. It is generally understood that this has been because European cities have a far greater number of inhabitants per square mile than do American cities, and because the cost of labor and material for properly maintaining a lighting system is less in Europe, the cost per inhabitant of lighting the streets being correspondingly reduced. It is probable,

however, that the principal reason is that the American public has not been educated to the value of an increased standard of street illumination. The standard has increased wonderfully in the last five years, but there is still room for great improvement.

The principal defects in the past have been the absence of a properly diffused light and the use of high brilliancy units so placed that they violate the physiological requirements for satisfactory street illumination. The introduction of the series tungsten lamp has, however, made available a highly efficient light source which is to a large extent free from these defects. Its long life tends to decrease maintenance costs. Its high efficiency insures low operating costs. Suitable reflectors may be used to deflect the rays of light to the more desirable directions, thereby increasing the effective candle-power, and still further reducing the cost for a given minimum intensity. Furthermore, the tungsten lamp has the proper color value for low intensities of illumination. A large list of sizes is available, and the practice of using the same size and type of lamp all over the city can be eliminated. And by the use of lamps of moderate candle-power, equipped with suitable screens or reflectors, the lamps may be advantageously placed at heights sufficiently low to avoid interference by adjacent foliage without producing a glare even approximately similar to that produced by arc lighting.

FIG. 2—STREET HOOD EQUIPPED WITH RADIAL TYPE REFLECTOR AND WIRE LAMP GUARD

The series tungsten lamps were first used to replace the series carbon filament lamps in residence and outlying districts. Between adjacent cross streets the lamps are spaced as close as local conditions will permit, and at cross streets two or more units of the same size, or a larger unit with the same distribution characteristics, are installed. The larger number of units, spaced at frequent intervals, afford a material improvement in uniform intensity of illumination, and a superior diffusion of the light which minimize the objectionable shadows common to all installations where a large volume of light flux issues from widely separated units.

Figs. 1 and 2 show types of reflectors and the auxiliary fixtures in general use for this class of service. Fig 3 shows a typical curve

of light distribution, with the reflector illustrated in Fig. 2. The illumination in foot-candles from 40, 50 and 75 watt lamps with radial type metal reflectors is given in Table I.

These lamps are occasionally operated in series with an arc circuit, but a series circuit composed exclusively of tungsten lamps is more generally used. Two systems of distribution are employed, known respectively as the "adjuster socket" and the "regulator" systems. Each has its own peculiar merits, and may be selected for use according to local requirements and, to a certain extent, according to the number of lamps to be employed. Both systems have an efficiency of about 96 percent. The adjuster socket system has a power-factor of over 99 percent, and the regulator system a power-factor of about 90 percent.

TABLE I.—ILLUMINATION IN FOOT-CANDLES WITH SERIES TUNGSTEN LAMPS AND RADIAL REFLECTORS.

	Height of Lamp.	40 Watt.		50 Watt.		75 Watt.	
		12 ft.	18 ft.	12 ft.	18 ft.	12 ft.	18 ft.
Distance from lamp to points along the street.	10 ft.	0.133	0.068	0.172	0.0865	0.258	0.1306
	25 ft.	0.052	0.039	0.065	0.0504	0.098	0.076
	50 ft.	0.0170	0.0150	0.0195	0.0179	0.0293	0.0273
	75 ft.	0.0068	0.0067	0.0085	0.0081	0.0122	0.0112

The adjuster socket system is intended for operation on constant potential circuits. It consists of a group of lamps connected in series across alternating-current mains. A small reactance coil is mounted in each street hood in parallel with the lamp, which operates to maintain the continuity of the circuit in case of burnouts or lamp removals. Great flexibility is possible when standard transformers are used to provide several different voltages for the lamp circuits. This system is particularly adapted to installations where the number of lamps is relatively small, since the cost of installation is quite low.

In the regulator system, the lamps are supplied with constant current from a regulating transformer. Each lamp is shunted by an insulating film cut-out which operates, in case of failure of the lamp, to short-circuit the lamp and thus maintain the continuity of the circuit. Since the tungsten lamp circuit is practically equivalent to a dead resistance load, it has been found that the ordinary regu-

lator will not operate satisfactorily. The standard design of repulsion coil constant-current regulator for operating arc lamps has one movable and one stationary coil, together with a suitable damping device to prevent extreme fluctuations. The damping device introduces a certain amount of friction into the mechanism of the regulator, but the current regulation is nevertheless quite close when operating arc lamps, since the lamps are constantly feeding and the inherent unstable operation of the arcs provides current fluctuations and consequent movement of the regulator coils sufficient to overcome the internal friction and keep the current reasonably close to the normal. With the tungsten lamp load there will be, of course, no such current fluctuations, and, to insure maximum life, a much closer regulation is necessary for the tungsten lamps than for arc lamps.

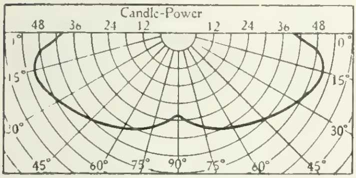


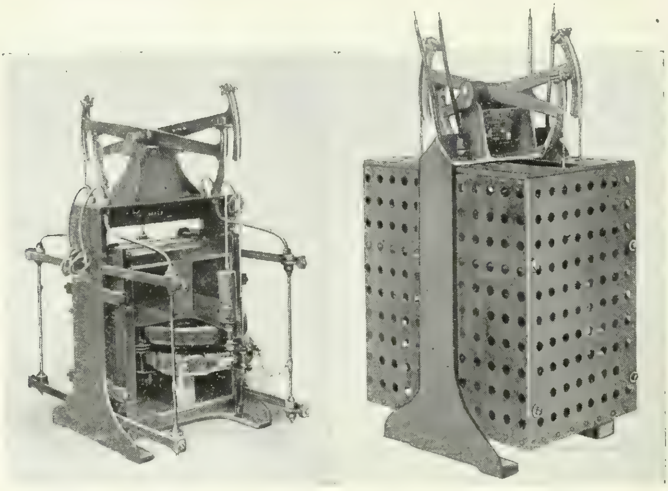
FIG. 3—CURVE OF LIGHT DISTRIBUTION FROM RADIAL TYPE REFLECTOR

On this account, a line of constant-current regulators especially designed for use with series tungstem lamps has been developed by the Westinghouse Electric & Manufacturing Company. They are of the repulsion coil type, but are made much more sensitive by the use of two moving coils, suspended by steel cables in such a manner that they just balance each other when the normal current passes through the secondary coil. These regulators will keep the lamp current within one percent of the normal for any load, and will take care of a lamp load equal to their rated kilowatt capacity plus a five percent ohmic and ten percent reactive line loss in the lamp circuit. The general appearance of one of these regulators is shown in Figs. 4 and 5.

Quite a new field for the tungsten lamp has been developed in the illumination designs for business sections. For this service the lamps are arranged in clusters of from two to five units. They are mounted on ornamental poles arranged to be fed from underground circuits and when equipped with suitable glassware represent quite a high order of decorative lighting. There are a few installations of multiple tungsten lamps supplied from a three-wire circuit. With this system of distribution one lamp on each pole is connected between one side of the circuit and the neutral, and the remaining lamps between the other side of the circuit and the neutral.

Ordinarily, it is not desired to have the entire number of lamps burn longer than 12 o'clock midnight. In such cases one side of the three-wire circuit is opened at the station, and only one lamp on each pole is left burning after midnight. There have been a few similar installations where three wires are not available and all of the lamps are connected directly across the multiple circuit with such switching devices at each pole as are necessary to permit an attendant to extinguish all of the lamps except one.

In the majority of installations, however, it has been found desirable to operate series tungsten lamps, particularly on account of their more rugged filaments and longer life. Such lighting has been



FIGS. 4 AND 5—CONSTANT-CURRENT REGULATOR FOR SERIES TUNGSTEN LAMPS
With and without cover.

in general on a decorative basis, and has been the result of a systematic campaign on the part of lighting companies. The property owners along the business streets have provided the poles and the tenants pay for the lamps on a yearly contract basis. This method of illumination has been very successful and satisfactory in the various installations to date, and at present is a very active subject in those cities where the lighting companies have succeeded in getting the public-spirited citizens interested in better street illumination. A few of the decorative pole forms which have been used in such installations are shown in Fig. 6.

The minor troubles experienced with series tungsten lamps for the illumination of streets have been traced to the exceptionally

bad line conditions which unfortunately exist in a great many cities. It is a matter of note that while central station managers have taken advantage of the many refinements in power station design, have installed the very best generating equipment available and have so regulated the power demands that the revenue is a maximum for the minimum station expense, they have only quite recently turned their attention to the efficiency of their distributing lines.

Summing up the situation, it may be stated that the advent of the tungsten lamp, with proper auxiliary fixtures, has made it possible to very materially improve street lighting. These lamps are very efficient, reasonably inexpensive to maintain, have fairly low intrinsic

FIG. 6—TYPES OF ORNAMENTAL POLES FOR TUNGSTEN STREET AND PARK LIGHTING

brilliancy (when equipped with suitable glassware), and best of all, are available in small units. These units have been spaced at more frequent intervals than has been the former practice, but they are not yet sufficiently close to secure the very best illumination results. It remains, therefore, for the manufacturer of illuminants and the lighting companies to inaugurate a system of education for the public, to teach them that the glaring appearance of a street lamp should not be used as a measure of its excellence, and finally to continually strive to raise the standard of street illumination in our cities to a point where the superior results will justly compensate for the increased cost.

HIGH SPEED STEAM TURBINES

EDWIN D. DREYFUS

A DISTINCT advance in steam turbine practice has resulted from the recent adoption of increased speed ratings. Curiously, this is a reversal of the order of the early progression in the industry, but, nevertheless, it is a very logical step on account of the remarkable improvement in the design and materials of construction. The earliest steam turbines, which were naturally of comparatively small capacities, were operated at speeds which were too high for direct commercial application. For example, one of the earliest Parsons turbines was operated at 18 000 r.p.m. and coupled to a bi-polar generator. While this machine was run for a short time, the speed was manifestly too great for regular service. In the De Laval type particularly, reduction wheels were used to secure the necessary slower speeds.

TABLE I

1 000 Kilowatt Turbine	Low Speed 1 800 r.p.m.	High Speed 3 600 r.p.m.
Length between bearings, approx....	12 ft. 7.5 in.	8 ft. 8 in.
Size of bearings, approx............	6 ft. 14 in.	4 ft. 9 in.
Weight, inc. blading, approx........	7 000 lbs.	2 000 lbs.
Maximum drum diameter, approx...	3 ft. 1.25 in.	20 in.
Minimum drum diameter, approx....	17.25 in.	10.25 in.
Number rows blading, approx.......	82	49

The rapid development in turbine work soon resulted in the attainment of speeds quite consistent with the capabilities of alternating-current generators and similar machinery receiving power at a uniform rate of rotation. When relatively larger sizes were reached, the rotative speeds were made much lower owing to the greater masses of material required to develop the larger amounts of power with the existing conditions in the mechanical and electrical art. More recent developments have effected notable changes in the relative proportion of turbines as a result of the adoption of increased speed ratings.

MECHANICAL STRENGTH

Increasing the speed for a given capacity might at first be viewed with disfavor, as usually high stresses and possible difficulties or dangers are associated with high speeds. To the uninitiated, doubling the speed of a turbine rotor would seem impossible within

the limits of safety, yet it is a fact that machines of the high and low rotative speeds are, in general, designed to operate with practically the same peripheral speeds. Hence, the centrifugal stresses and the maximum fibre stresses in the two cases may readily be brought to the same point. In other words, the two machines may be designed with equal assurance that the same factor of safety will exist in the completed structures. Herein, however, is involved a point which is distinctively in favor of the high speed machine. Being of much smaller diameter, the spindle drums will afford a much greater surety of homogeneous metal than in the case of the

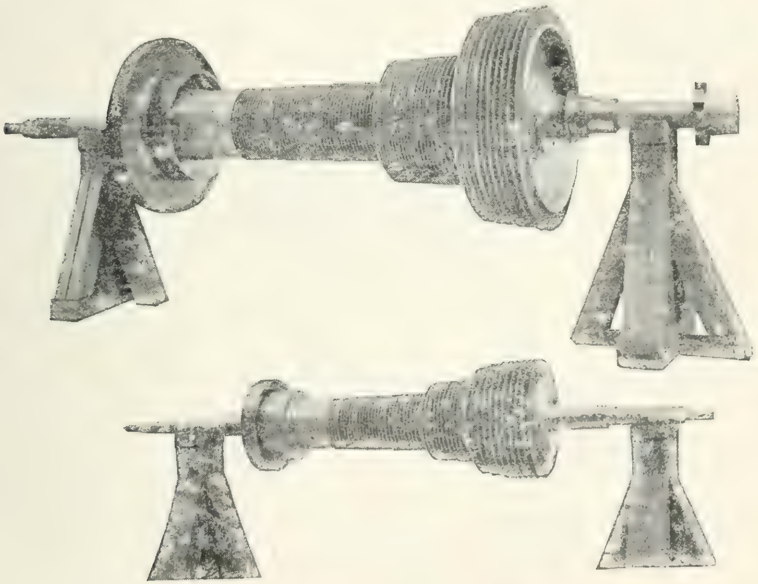


FIG. 1—COMPARATIVE SPINDLE SIZES
1 000 kw turbines for speeds of 1 800 and 3 600 r.p.m. respectively.

larger masses; i. e., the possibility of internal flaws, or other differences in the metal at various points of the rotor will be minimized in the machine of smaller dimensions. For this reason, it is good practice to design the slower speed machine with slightly less peripheral speed than would perhaps be desirable, beause of the greater uncertainty in character of the larger masses of metal.

A general comparison of some of the principal dimensions of two 1 000 kilowatt standard turbines, one to operate at a speed of 1 800 r.p.m., and the other at 3 600 r.p.m. is given in Table I. From this table it may be seen that the length of the spindle of the high

speed machine between bearing centers is approximately 30 percent less than that of the lower speed machine. This has been made possible by the use of smaller blade sections and fewer rows. The decrease in the number of rows has in turn been brought about by the altered steam distribution. The general reduction in dimensions is best shown in the weight of the two spindles and the maximum drum diameters. As relatively longer blades are permitted in the high speed machine, this decreases the effect of leakage across the tips, especially in the high pressure section.

A visual comparison of the relative sizes of the rotors for two 1 000 kilowatt units, the larger one designed to operate at a speed of 1 800 r.p.m., and the other at 3 600 r.p.m., is given in Fig. 1. In taking these photographs the rotors were each placed on the

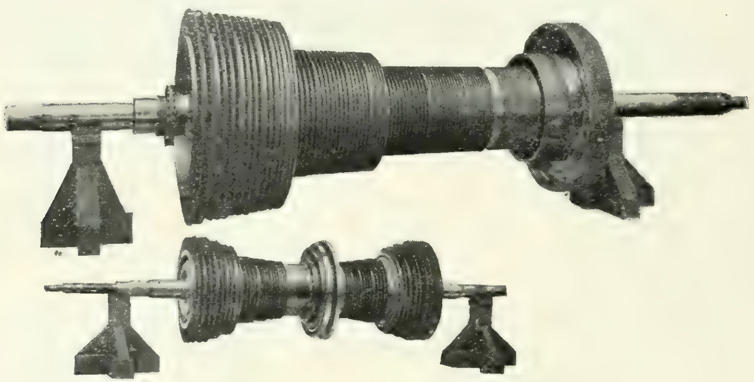


FIG. 2—COMPARATIVE SPINDLE SIZES
2 000 kw turbines, 1 200 and 3 600 r.p.m. respectively.

same "horses" and the camera placed at the same distance from each rotor. From the illustration the reduction in the amount of metal and the modified proportions of the rotors are evident. The new high speed design has been successfully developed after much careful experimentation and study with the result that improved economies are obtained over those of the slow speed type.

In turbines of 2 000 kilowatt capacity designed for similar speed increases, the change in the construction becomes even more pronounced as in this case the double flow design* with its inherent advantages may be used. In this case also the number of blades is reduced and more efficient blading is secured. Fig. 2 shows, in a

*A description of the double flow turbine by Mr. R. N. Ehrhart appeared in the JOURNAL for October, 1908.

manner similar to Fig. 1, the comparative construction of the rotors of two 2 000 kilowatt turbines on a comparative scale. The larger rotor is designed to operate at a speed of 1 200 r.p.m., and the double flow type at 3 600 r.p.m. In this case the comparison is even more striking, and a shortening between bearings of approximately 35 percent is obtained.

BEARING DUTY

It might be supposed that the higher speed machines would present greater bearing difficulties, but the problem is no more difficult than for the lower speed machines. In the design of shafts and bearings, the primary consideration is the bending element due to the weight of the revolving mass, twisting moments being of relatively small importance. Therefore, the heavier the revolving mass and the greater the distance between centers of bearings, the larger the diameter of journal and bearing area necessary; and, conversely, the smaller the revolving mass the less the bearing surface required. Consequently, with the higher speed turbines having smaller rotors (less weight and shorter distance between supports) smaller bearings may be employed, and furthermore, the unit pressure per square inch of projected area may be confined within as wide a margin of safety as that of the low speed machine. As no difficulty has been experienced with the low speed turbines, there should be no concern regarding the machines of higher speed.

In order to determine completely the results of varying pressure loads per unit of projected area and surface velocities, and also ascertain the limitations to which the bearings could be subjected without signs of distress, thorough bearing experiments have been conducted in the East Pittsburg shops within the last few years. A large steel forging of dimensions and weight practically equal to the rotor of a large generator unit of 7 500 kilowatts at 1 500 r.p.m. and approximately 70 000 pounds weight, was prepared for test. Increased unit bearing pressures were obtained by shortening the bearings and tests were run with pressures up to about 300 pounds per square inch of projected area and with surface velocities as great as 80 feet per second, which is three to four times the maximum contemplated duty.

The bearings were run a sufficient length of time to insure no further increase in temperature. These experiments were carried out so extensively as to dispel all doubts as to the suitability of the bearings for the higher speed machines.

Lubrication is as well provided for as in the lower speed machines in having ample flow of oil to dissipate heat generated in the bearings.

BLADE CONSTRUCTION AND ECONOMY

Although the same constructive features are retained in both cases, there is an inherent gain in economy in the high speed machine. As the diameter is reduced (practically one-half), the proportional blade lengths as referred to the drum diameters are in-

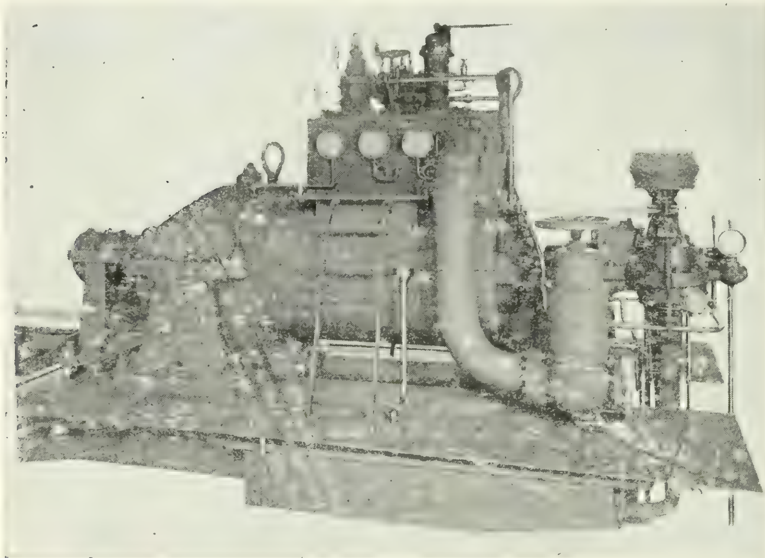


FIG. 3—MODERATE SIZE HIGH-SPEED TURBINE
1 000 kw, 3 600 r.p.m.

creased and are, therefore, more efficient as the relative leakage is much less than in the large diameter machine. Conversely, relatively greater clearance can be used without sacrifice in economy. But, on the other hand, high speed machines, having cylinders of smaller diameter, are subjected to less distortion, and can be safely operated with finer clearances than the slower speed machines. This is taken advantage of in the design of the high speed turbines, resulting in marked improvement in economy; approximately five percent for the greater part of the load range in high pressure work, the greater proportion of the leakage occurring in the high pressure stage.

Official tests of two 1 000 kilowatt turbines furnished the United States Government, operated at 1 800 and 3 600 r.p.m., respectively, showed an improvement in efficiency of 4.5 percent for the higher speed machine.

FLOOR SPACE

The new high speed units lend themselves admirably to the general tendency to reduce the floor area per unit of capacity in modern power station practice. A reduction in length of machine over metal parts of 15 percent is effected by doubling the speed of machines of 1 000 kilowatt capacity. In width the decrease is not quite so much, amounting to very little in small machines and to about 12.5 percent in the larger sizes.

FIG. 4—LARGE HIGH-SPEED DOUBLE FLOW TURBINE
10 000 kw capacity, 1 500-1 800 r.p.m.

There have been quite a number of high speed turbines installed. Turbines of 10 000 kilowatt capacity formerly operated at 750 to 720 r.p.m., are successfully designed for 1 500 and 1 800 r.p.m. In addition to the advantages already mentioned, the higher speeds tend toward very much more symmetrical appearance. Figs. 3 and 4 will give an idea of the more attractive appearance of this new type of turbine.

RECENT INVESTIGATION OF LIGHTNING PROTECTIVE APPARATUS*

R. P. JACKSON

[This is the third of a series of articles on the general subject of continuity of service in transmission systems, dealing particularly with line stresses and static troubles, and the proper protection of transmission systems from such troubles.]

OWING to the peculiar nature of lightning and similar disturbances, a variety of opinions continues to exist concerning their action and the usefulness of various devices for protecting against them. In this paper an attempt is made to outline the most dominant characteristic of lightning as manifested on electric circuits and recent investigation as to what characteristics protective devices should possess and to what degree they have been found in practice to possess them.

A MECHANICAL ANALOGY

In many ways the various characteristics of electric circuits can be represented by mechanical analogies; though no one analogy will hold good for all the phenomena. The following analogy is new, and is especially well fitted to represent the static elements of an electric circuit.

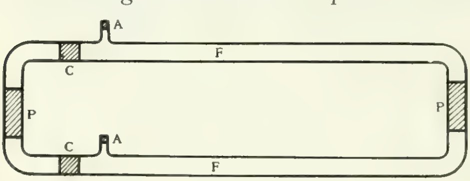


FIG. 1

Assume an elastic fluid like a heavy gas having inertia and capable of various states of pressure and motion without changing its characteristics. Enclose this fluid so as to flow in directed paths, such as pipes, and provide pistons, such as shown in Fig. 1, one of which may receive power and the other deliver it. If one of these pistons is moved back and forth, the fluid in the pipes is compressed and expanded in turn while the other piston moves a little later in phase and may do work. The amplitude of motion determines the flow of fluid.

Electrically, one of these pistons may be considered as representing a generator and another a translating device, such as a transformer. The ability of the fluid to be compressed and expanded corresponds to the electrostatic capacity of the line, while

*Revised by the author from paper read before the American Institute of Electrical Engineers, December 28, 1906.

the inertia and frictional resistance to the motion of the fluid represent respectively the inductance and the resistance of the line.

Choke-coils may be represented by smaller pistons *CC*, of considerable inertia, but moving freely in the pipe. It may be noted that the pistons *PP*, which represent the generator and transformer, likewise have inertia, but are also moving against the resistance of their load or the work that is being done. Small plugged vents *AA* are the equivalent of the lightning arresters. The resistance to the flow of fluid through them after the plugs have been ejected corre-

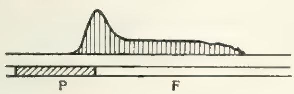


FIG. 2

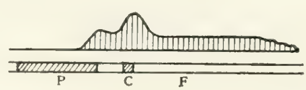


FIG. 3

sponds to the series resistance of the arrester, while the security with which the plugs are held represents the length of gap. It is obvious, of course, that very small holes for vents will give correspondingly little relief in case a rise of pressure develops. A larger hole will give a greater degree of relief from excess pressure, and the size of vent necessary to limit the pressure at a given point to any value is dependent on the rapidity with which the fluid at any objectionable higher pressure can reach the vicinity of the vent. The result of numerous experiments indicates that a true conception of the effect of lightning and other static phenomena, on transformers and generators, is only to be had by considering them as analogous to cases of impact of surges in an elastic fluid.

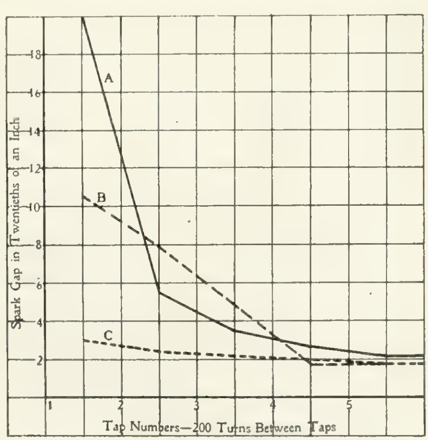


FIG. 4

Assume that an explosion has occurred at some point in the pipe, Fig. 1, and that this explosion has had the effect of producing for some length of the pipe an immensely increased pressure. This fluid, if retained in the pipe, will expand in each direction with a rapidity controlled mainly by the inertia and elasticity of the fluid.

If this wave of high pressure strikes a piston of great inertia an additional rise of pressure and also a reflection of the wave will occur. If it is especially desirous that the pipe be kept from bursting near the piston, or if it happens to be impossible to make the pipe as strong near the piston as elsewhere, there are two devices which serve to relieve the stress at that point. They are indicated in Fig. 1 and operate in different ways.* A loose piston of considerable inertia will reflect part of the wave before it reaches the main power piston and so relieve the strain on the pipe in the vicinity of the latter. Also a suitable vent will permit the escape of sufficient fluid to limit the rise in pressure.

This analogy may be applied to electric circuits in the following manner: If a wire becomes inductively charged for a portion of its length by a cloud overhead, and this cloud discharges to ground, a free charge suddenly exists on the wire and at once expands in both directions with about the velocity of light. If this charge escapes at some point through a certain amount of inductance, oscillations will, of course, be set up. Under proper conditions the elastic fluid assumed in the analogy will act in the same manner. The probable effect, however, is simply that this charge in expanding strikes the transformer with a terrific impact. The inductance or electrical

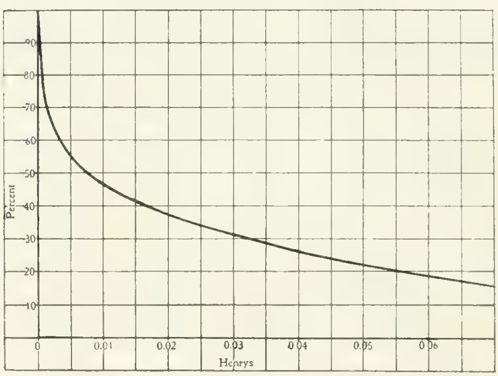


FIG. 5

*An attempt to make an analogy include all the phenomena of electric circuits leads to burdensome complications. It may be observed that pistons are only suitable to illustrate or represent inductances where the flow of the fluid is considered to be alternating. A true analogue is to assume a heavy pivoted mass like the rotating part of a steam turbine. After such a mass had been set rotating by continuously flowing fluid, it would offer no further impediment to flow, except the incidental frictional resistance, just as inductance acts with continuous current. If such a mass be equipped with a multitude of small vanes, there will be, while the mass is being accelerated, a difference in pressure from one end to the other, manifested by the fluid driving or accelerating the mass. A heavy surge in the fluid striking the vanes might bend or break some of the first row or circle before the mass could be accelerated. This represents in some degree the breaking down between turns of electrical apparatus.

inertia of the transformer causes the surge to bank up in a manner similar to water-hammer in a pipe. A rise in pressure and a partial reflection occurs, dependent in amount on the suddenness of impact or steepness of the wave-front of the surge. It should be noted that though this illustration is used because water-hammer is a familiar phenomena, the analogy is not entirely true, inasmuch as water is not elastic as is gas.

It is the effect above noted that causes the bursting of transformer and circuit-breaker bushings, though their insulation is

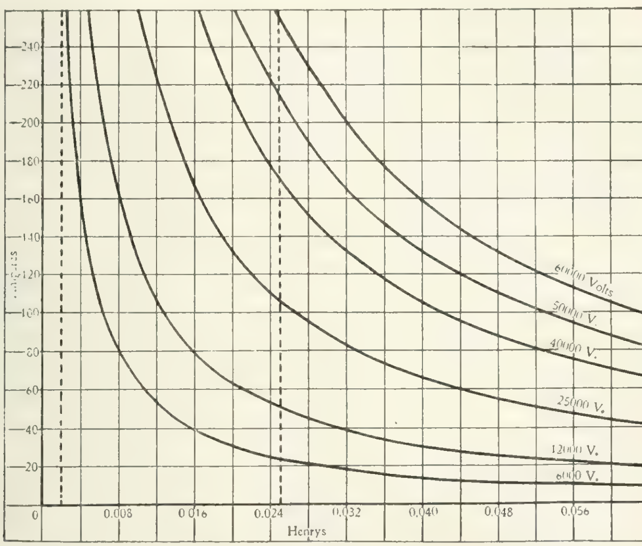


FIG. 6—CURVE SHOWING INDUCTANCE TO GIVE ONE PERCENT DROP AT 80 PERCENT POWER-FACTOR, 25 CYCLES

stronger than that of the line from which the surge comes. The pressure near the transformer terminal is greater, perhaps twice as great, as it is at some distance back on the line. Fig. 2 shows what might be an instantaneous condition when *F* represents the line and *P* the transformer winding.

Now to revert to the analogy, it can be assumed that inertia is represented by the pistons *CC* and there can be inserted its electrical equivalent, an inductance or choke-coil. Apparently a well-insulated choke-coil in the lead of the transformer simply divides this impact into two parts, as shown in Fig. 3. The wave form does not, of course, represent an instantaneous condition, but rather the two maxima with a slight time-interval between. They are, of course,

two separate reflections; one from the choke-coil, and one from the transformer winding.

It should be noted that there are two stresses; one from the conductor to ground, the other between different parts of the same conductor. In Fig. 2, there is a large difference of potential between the lead and a point a short distance in on the winding. This is the cause of the breaking down between turns of transformers and generators, one of the most common manifestations of lightning trouble.

As indicated in Fig. 3, there is for an instant a large difference of potential between the terminals of the choke-coil, and a moment later a condition similar to that in Fig. 3 occurs in the transformer, but to a less degree. The amount of inductance in the choke-coil determines the amount of impact taken up by the coil and the corresponding relief to the transformer.

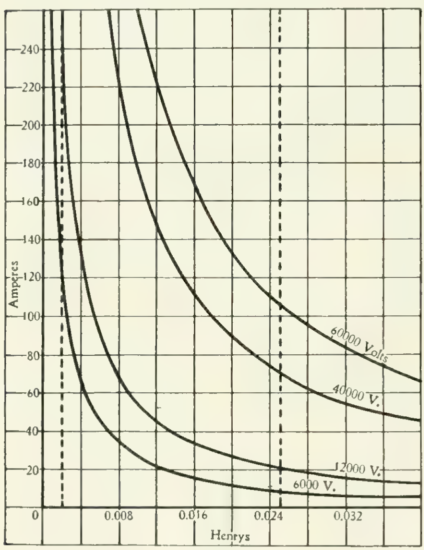


FIG. 7—CURVE SHOWING INDUCTANCE FOR CHOKE COILS GIVING ONE PERCENT DROP AT 80 PERCENT POWER-FACTOR, 60 CYCLES

The way in which these stresses are distributed in a transformer winding is shown in Fig. 4. A 30 000 volt transformer winding of 2 000 turns had leads brought out every 200 turns. It was arranged to have a condenser of 0.1 microfarad capacity, charged to about 50 000 volts, discharge into and through this transformer. Spark-gaps were placed between adjacent leads, in each case spanning 200 turns. Fig. 4 shows the curve for only half the transformer winding. Curve *A* shows the rise in pressure across each section when unprotected. Curve *B* shows the result when a choke-coil of 0.0165 henry is placed in the lead. Curve *C* indicates the flattening effect on the potential distortions within the transformer when a choke-coil of 0.1764 henry is used.

It would appear that the first turns in an unprotected transformer take the greater part of the strain and they also act as a choke-coil to the rest of the transformer. The reduction in stress across the first ten percent of the windings by the use of the external inductance is obvious. The result on the first ten percent of the windings where various inductances from zero to 0.07 henry are used is shown in Fig. 5. With no choke-coil, the stress appearing across the leads *1* and *2* is taken at 100 percent. With the different choke-coils the lower values indicate the percent that may still be said to pass through the choke-coils and appear as stresses across the first 200 turns of the transformer windings.

A flatter wave-front would, of course, tend to make curve *A*, Fig. 4, approach curve *C* and the curve of Fig. 5 would have a lower maximum but would probably take the same shape; that is, the same coil would allow the same percent of the maximum rise to pass into the transformer, independent of the wave-front.

A transformer of different design would also probably give a similar curve, except that for the same surge a different proportion of the windings would be required to give the same rise in pressure. In other words, it does not appear to be a certain percent of the transformer winding that receives the shock, but it is more probable that the first inductance encountered by the surge receives the stress to a certain depth measured from the end of the winding which first receives the blow. If external inductance is inserted, the amount of the stress taken up by it will depend on its amount. Therefore a transformer of a very few turns would naturally have such an impact stress distributed over most of its windings, while one of many turns is only endangered in the first small percent of its windings. As the inductance of any coil is, in general, proportional to the product of the mean turn and the square of the number of turns, it follows that the larger a transformer, the better is its inherent insulation against the impact stresses. For example, assume two transformers that at the same frequency will give 25 and four volts per turn respectively; presumably one will have insulation for 1 000 volts total between the first 40 turns, while the other will be provided with the same amount of insulation distributed over the first 250 turns. The same inductance encountered in the first 40 turns of the larger transformer will, however, be found in the first 63 turns of the smaller. The insulation of the latter would normally be for only 250 volts, there being only one-fourth the number of

turns required for 1 000 volts operating potential. Consequently the smaller transformer, while suitably insulated for its operating condition at normal frequency, is not so well protected against surges as the larger one.

In a general way the curve of Fig. 5 is borne out by results from coils in use. Coils of low inductance have in some cases permitted sufficient disturbance to penetrate to damage the transformers, while the better type of oil-insulated coils have been such good reflectors that the only difficulty has been in maintaining the insulation of the coil itself against the banking up of potential across it.

FIG. 8—OPERATION OF EXPULSION FUSE

No. 30 copper wire: impressed voltage, 38 000 volts to ground; generator capacity, 75 kw: 23 miles of line between power-house and fuse, and no other impedance to limit current of short-circuit. As may be noted in Fig. 9, the short-circuit lasted but one-half wave before being interrupted by the fuse. There is no apparent rise of voltage following this action.

A reasonable deduction from Fig. 5 is that coils of very low inductance are practically useless; while for coils of inductance greater than 0.06 henry the protection increases very little with the increase of inductance in the coil.

Moreover, with increase of inductance in the choke-coil another difficulty is encountered. These inductances, of course, produce a drop in voltage. The electromotive force across the terminals of a coil is proportional to the current in that coil, but ap-

proximately 90 degrees out of phase with the current. Hence when the power-factor of the load is nearly unity the resulting drop in voltage is relatively very small. If the power-factor of the circuit is low, however, the electromotive force across the choke-coil comes more into phase with the impressed voltage and becomes of consequence. Fig. 6 and 7 show curves based on inductances giving one percent drop per coil at 80 percent power-factor at 25 cycles and 60 cycles respectively. Thus in a single-phase circuit with a coil on each side of the circuit, the drop at full load and 80 percent power-factor would be two percent. This value is simply assumed as a possible extreme maximum. With power-factors near unity, even these inductances would not cause an appreciable drop.* From Fig. 5 it would seem that from 0.002 to 0.025 henry should be the useful range of values from the point of view of protection. Figs. 6 and 7 indicate to what degree such inductances may be used.

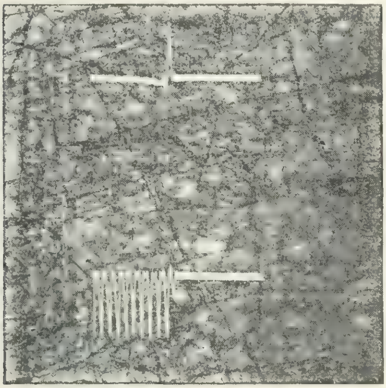


FIG. 9—CURRENT AND VOLTAGE OSCILLATIONS

Showing effect on circuit of operation of expulsion fuse illustrated in Fig. 8. Upper record, current: lower record, voltage. The displacement of the voltage record from its normal position symmetrical to the zero line is probably caused by a grounded oscillograph circuit.

From these it appears impossible to obtain much choke-coil protection from 60-cycle circuits of low voltage, low power-factor and large currents on account of the prohibitive drop. In all other cases shown a suitable inductance may be inserted with a permissible drop. For higher voltages, the percent drop will be negligible. Also if the power-factor of the load is near unity, even such inductances as may have been indicated as desirable will not cause an appreciable drop. In most circuits, a well insulated coil of considerable inductance is of undoubted service.

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*A rough rule for determining the inductance of a choke coil without iron is to multiply the square of the number of turns by the length of the mean turn in inches and divide the product by 10^8. This gives approximately the inductance in henrys..

EXAMPLE:—A certain oil-insulated choke-coil had 186 turns and the length of the mean turn was 66 inches. Then its inductance was equal to

$$186^2 \times 66 \times 10^{-8} = 0.0228 \text{ henry.}$$

From consideration of Fig. 4 it would apparently be possible to insulate a transformer so as to protect it against probable surges, but it would make a difficult and expensive design at best and, under commercial conditions when various loops are required and perhaps also series and parallel operation of coils for full and half voltage, such insulation would be impracticable.

THE LIGHTNING-ARRESTER

Returning to the mechanical analogy and Fig. 1, it may be noted that the lightning-arrester is of the nature of a relief valve which,

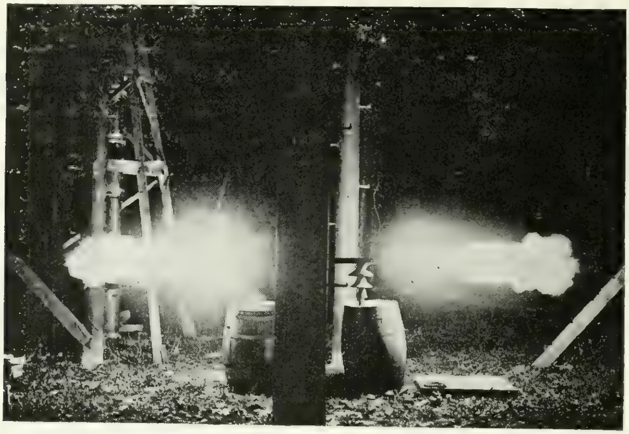

FIG. 10—OPERATION OF EXPULSION FUSE*

No. 22 copper wire; otherwise, same conditions as those for Figs. 8 and 9. As indicated in the oscillograph records taken from the circuit during the action of the fuse, the short-circuit lasted two complete waves. It appears to have occurred late in the first wave and to have been interrupted during the second wave before full amplitude had been attained. This, however, may have been due to other causes. In both Fig. 9 and Fig. 11 the oscillograph films moved from left to right, so that the sequence of waves is from right to left.

when a rise of pressure occurs at the point at which it is placed, should permit the escape of a sufficient amount of the elastic fluid to limit the rise of pressure. Considering the condition previously suggested, of a surge of the elastic fluid towards the piston representing the transformer, it is possible, if the size of the pipe and the velocity of the moving fluid is known, to determine how large a

*All oscillographs were taken by the Ontario Power Company, Niagara Falls, Ont., while the fuses were blown and the photographs taken at the Lockport station of the Niagara, Lockport & Ontario Power Company, N. Y.

vent will be required to relieve the surge of the fluid as fast as it arrives, without permitting any reflection. Now supposing similar conditions to exist in an electric circuit, can any tangible result be deduced? It has been shown that electric impulses or waves travel along aerial conductors with a velocity approximately equal to that of light or electromagnetic waves in the ether.* Also the charge or amount of electricity per unit length of conductor is proportional to the electrostatic capacity of the conductor, and the potential to which it has been raised, in the same way that the amount of fluid in the pipe is proportional to the volume per unit length and the pressure.

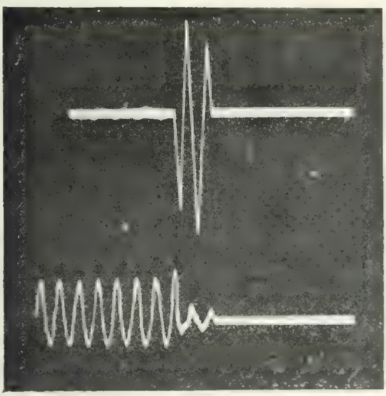

FIG. 11—CURRENT AND VOLTAGE OSCILLOGRAMS

Showing effect of operation of expulsion fuse as illustrated in Fig. 10. Upper record, current; lower record, voltage. The voltage is seen to become normal after the short-circuit has been opened.

Now considering, in the case of the pipe, that the initial condition of the elastic fluid before being disturbed was that of very low inherent pressure, the wave resulting from the re-distribution of sudden local high pressure will produce a mass velocity of the particles of the fluid itself very nearly equal to that of its velocity as a wave. On the other hand, if the normal pressure is such that the disturbance represents only a small percent change, the mass velocity of the fluid composing the wave at a given instant will be small compared with that of the wave itself. The latter condi-

*The rate of travel of electric waves along a wire is not a fixed value, but depends on the distributed capacity, the resistance, and the inductance of the line. This rate of propagation in miles per second is given by the expression,

$$\sqrt{\frac{2\omega}{C\left\{\sqrt{R^2 + L^2\omega^2} + L\omega\right\}}}$$

["Alternating Currents," Bedell and Crehore (1893), p. 199.]

if C, R and L are given in farads, ohms, and henrys per mile, respectively. It may be found from this expression that for all sizes of copper down to No. 6, which is about two ohms per mile, and for all frequencies down to 150 cycles per second, the rate of propagation is not reduced more than ten percent from the maximum. Consequently, as surges are in general of much higher frequency than 150 cycles their rate of propagation may be taken as being approximately equal to that of light.

tion is that existing in the case of ordinary sound waves. If, however, a tremendous explosion occurs, the wave of air is accompanied by a large mass motion. The action in the former case, or that of low inherent pressure, is also similar to that which will occur in a pipe when a valve is suddenly opened and closed, permitting the escape of an elastic fluid from a reservoir into the empty pipe. If this fluid is heavy and encounters little resistance, it will impinge on the closed end of the pipe and rebound. The action in an electric con-

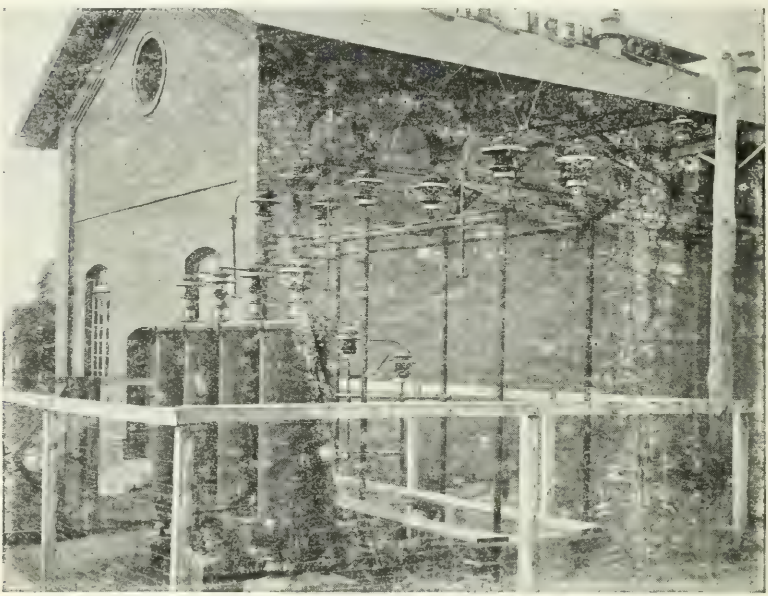

FIG. 12—INSTALLATION OF ELECTROLYTIC LIGHTNING ARRESTERS ON 44 000-VOLT, THREE-PHASE POWER TRANSMISSION CIRCUIT

Showing arc on horn gap at moment of discharge from all lines to ground. Southern Power Company.

ductor under a servere disturbance, is more truly represented by considering the normal pressure very low compared with that produced by the disturbance. This would at least be true if the sudden rise should occur at or near the zero of the electromotive-force wave.

The above illustrations are simply to show the reasoning which leads to the following deduction. Assume that a potential wave of irregular contour is approaching a transformer protected by a lightning-arrester. Assume some part of this wave to have a value of 100 000 volts. If the electrostatic capacity of the conductor to ground is taken as 0.0135 microfarad per mile, which is approxi-

mately correct for the ordinary transmission line, there will be a charge of 0.00135 coulomb per mile. If this charge is arriving at the rate of 186 000 miles per second there are 0.00135x186 000 or 251 coulombs per second or 251 amperes to be disposed of, which if divided into 100 000 gives 400 ohms, the non-inductive resistance that would just let this surge escape without reflection if used as a series resistance to the arrester. If the potential of the incoming surge is higher or lower the charge per mile becomes correspondingly higher or lower, and this critical value of resistance would remain the same. If there were some kind of recording meter capable of operating under such conditions, placed where the vent

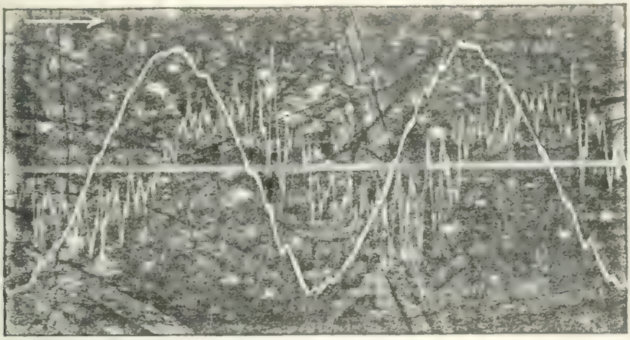

FIG. 13—OSCILLOGRAM SHOWING VOLTAGE AND CHARGING CURRENT ON ELECTROLYTIC CELL

The effective value of current is less than 0.5 ampere. Note phase displacement between current and voltage (leading current).

is connected, it would leave a record of the potential of the arriving charge, or to some degree the contour of the wave or surge. If a resistance greater than the critical value is used there will be a partial rise and reflection and a partial escape; but if the resistance is of less value the surge of potential striking the transformer windings will be similar to the contour of the incoming wave but of lower value. If, in the extreme case, there is no resistance, the charge will escape as rapidly as it arrives. In the case of the pipe and elastic fluid analogy, if the vent is too large the inertia of the moving fluid may produce a partial vacuum with a resulting return flow or oscillation. This may, of course, also occur with the electric discharge, but it is possible that the inevitable resistance of the ground connection will limit any such effect.

From the above considerations it appears that the series re-

sistance of an arrester should be very low and not greater than 400 ohms in any case, if the arrester is properly to serve its purpose. The reasoning and calculation given is perhaps a rough way of reaching the result, but it is on the whole not far from the truth, and it is in accord with the writer's experience. No exact formula can be applied absolutely to such irregular phenomena, but if the general assumptions are correct the result forms a guide sufficient to enable us to recognize and dispense with useless devices.

Having disposed of the series resistance from one consideration it is found, however, that no arrester with a reasonable gap will disrupt its dynamic arc if the circuit is carrying power from generators of large capacity unless the power circuit is limited in some way. By using multigaps of non-arcing metal of such number that a rise of 300 percent will just break over, and then adding an equal number of gaps shunted by resistance, an arrester may be made

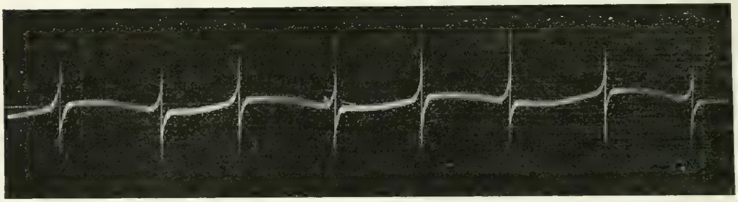

FIG. 14—OSCILLOGRAPH RECORD OF THE VOLTAGE OF AN ALTERNATING-CURRENT CIRCUIT WITH VIOLENT SURGES OR STATIC AS THE RESULT OF ARCING TO GROUND AT SOME PLACE IN THE CIRCUIT

Abnormal condition in circuit.

which on moderate power will disrupt its arc without the use of series resistance; but if the gaps are limited to such a number as to break over with a potential of from 150 to 200 percent of normal and there is no limiting resistance, the arrester will almost invariably burn up before many discharges have passed over it.

A COMPARISON OF ARC-SUPPRESSING DEVICES

The two devices most generally used for disrupting the arc in an arrester are the horn-type gap and the non-arcing metal multigap. On circuits where the power is so limited that the short-circuit current is not more than 50 amperes, either device should work without series resistance. Where the power is very large, however, as on the usual transmission line, the non-arcing metal is superior to the horn-type, in that the arc is easily suppressed with a much lower resistance, and suppressed more quickly.

It was found on a voltage of 38 000 volts to ground from a three-phase, 7 500 kw plant that a resistance of 300 ohms is sufficient with the non-arcing multigap type, while a resistance of 1 000 ohms is required for the proper operation of the horn-type. This shows that the devices are comparable in arc-suppressing power, but that one is much more powerful than the other, and in operating causes less disturbance to the circuit, because it takes so much less time to do its work. On the other hand, the horn may be placed out of doors, if necessary, while the multigap should be under cover.

Multigap devices for the higher voltages are, however, subject to some peculiar troubles of their own. In regard to the matter of the voltage at which a multigap arrester will break over, an important fact has been demonstrated; the influence of the potential surrounding bodies has a marked effect on the break-over voltage.

FIG. 15—OSCILLOGRAPH RECORD OF VOLTAGE OF THE SAME CIRCUIT AS SHOWN IN FIG. 14 BUT WITH AN ELECTROLYTIC ARRESTER IN THE CIRCUIT

Abnormal condition almost completely suppressed by electrolytic cell.

For instance, an arrester of the multigap type that would break over at 75 000 volts when located in the open or away from walls or ground would, when placed near the ground or mounted between cement barriers, spark over at 40 000 volts. The ability to disrupt the arc apparently falls in about the same proportion. This phenomenon is the result of unequal distribution of the potential stresses over the various gaps. If the potential gradient over the gaps is uniform, the maximum breakdown value will be obtained. The influence of surrounding grounding material is to increase the steepness of the gradient near the line end of the series of gaps and flatten it at the ground end. A metallic shield near the line end of the gaps which is connected to the line will correct this gradient and bring the breakdown value back to normal. For the higher

voltages multigap arresters should be protected in this way, if mounted in close proximity to grounded material.*

THE GAP AND FUSE ARRESTER

Considering the effect of a resistance on a discharge path according to the mechanical analogy, it appears desirable at times to provide something in the nature of an absolute relief vent. A gap and a fuse of fine wire will serve this function best, but the fuse should be of either the enclosed form or of the expulsion type. An open wire fuse will almost invariably take so long to suppress its arc that it is likely to open the circuit-breakers, while the same wire enclosed in a tube will open its arc in one or two alternations. There are shown herewith photographs and oscillograms of fuses blown on a generator capacity of 7 500 kw, three-phase, and at 38 000 volts from one side of the line to ground. It may be seen

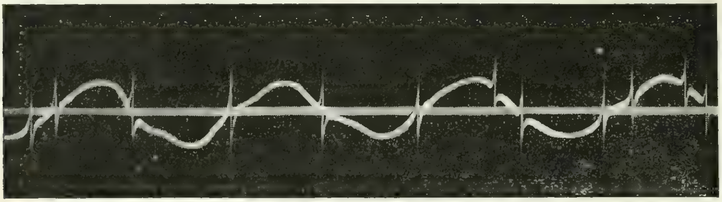

FIG. 16—OSCILLOGRAPH RECORD SHOWING DISCHARGE CURRENT THROUGH ELECTROLYTIC ARRESTER WITH VIOLENT STATIC PRESENT DUE TO AN ARCING CONDITION OF THE CIRCUIT

Showing how discharge passed through cell, thereby relieving voltage stresses as indicated in Figs. 14 and 15.

that the No. 30 copper wire opened at the end of one alternation, while a No. 22 copper wire lasted two full waves. The fuses were blown at the end of 23 miles of line, but no serious rises of potential are shown. With the larger fuse, the first voltage wave after the fuse opened shows a rise of about 20 percent. The circuit-breakers were not tripped at any time, although there was a generator capacity of 5 000 kw on the circuit at the time.

Experience shows that several gaps and fuses may be placed in parallel, and usually only one fuse will blow at a time. From the fact that so little secondary disturbance is caused on the line, such fuses appear to be an excellent expedient to use where the lightning disturbances are liable to be too severe to be relieved by a self-restoring arrester.

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*See article on "Multigap Lightning Arresters With Ground Shields," by Mr. R. B. Ingram, in the JOURNAL for Aprii, 1907, p. 215.

THE ELECTROLYTIC ARRESTER

It is evident, therefore, that what is really needed is a device having the characteristics of a safety valve; that is, something that will hold the operating pressure at all times, but furnish such a free vent that no pressure much above the normal can be maintained, no matter how suddenly such abnormal pressure may occur. Such a device has been found in the aluminum electrolytic cell.

In certain electrolytes, aluminum forms a non-conducting film on its surface. This film is very thin, comparable in dimensions to a wave length of light—but in a suitable electrolyte will withstand a voltage of 380 to 400 volts. Above this voltage, the film will be punctured with myriads of small holes letting a large current through, but resealing again as soon as the pressure is reduced. The equivalent spark gap of such a cell is a function of its dimensions, and it is a simple matter to make a unit suitable for 10 000 volts potential which will have an equivalent gap representing 12 500 volts. If a horn gap, which will also break at 12 500 volts, be placed in series with the cell unit, the equivalent gap of the combination will still be approximately 12 500 volts. In other words, the severest discharge from a condenser representing several miles of line and charged to 50 000 volts representing artificial lightning, will pass through the device without a potential of more than 12 500 volts existing over its terminal.

This cell can be connected in series with a suitable gap between each line and ground, and will suppress all abnormal rises of potential at the point of connection. As to the kind of gap, a non-arcing multigap has been found very satisfactory, while a small horn gap seems to work nearly as well. As the normal frequency current taken is below one ampere, the arc rises a few inches on the horn and goes out quietly. A surge or electromotive force peak from any source is allowed to pass and relieve the line, exactly as in the case of a safety valve, while the power current which can follow is insignificant. This characteristic is well illustrated by the oscillograms given in Figs. 13, 14, 15, and 16.

STEAM ENGINE vs. MOTOR DRIVE FOR SMALL MACHINE SHOPS

A. G. POPCKE

IN laying out new machine shops, the use of motor drive either for individual machines or for groups of machines is becoming almost universal. There are, however, many machine shops which were equipped with steam engine drive and mechanical transmission quite a number of years ago, when that was the best system available and electric motors were not commonly used.

Small machine shops of this kind may conveniently be classified under two headings; first, those operated by the owner, and, second, those rented or leased by the operator. Where there are a number of small shops in one building, power is quite commonly furnished to all floors and in some cases the charge for it is included in the rental.

PLANTS OPERATED BY OWNER

With steam drive in such a building, some or all of the following conditions are usually encountered:—

1—Heavy vertical transmission to all floors.

2—Quarter turns for right-angle transmission.

3—Much valuable space occupied by belts, pulleys and shafts.

4—Lost motion toward the end of the transmission.

5—The services of an engineer are required.

6—Overtime work causes excessive proportionate expense for power.

Heavy vertical transmission requires the use of very wide belts or idler pulleys to prevent slipping. These wide belts and pulleys not only consume much energy in friction loss, but also are expensive and occupy valuable space. In one six-story building where the steam drive with vertical transmission was considered fairly satisfactory, the owner was much surprised to find that 35 horse-power (about 10 percent of the engine capacity, 350 horse-power) was required to drive the pulleys, belts and jack shafts of the vertical transmission when the shafting on all floors was disconnected by means of clutches. He could easily comprehend that the friction is still greater when the machines are working; moreover, he could see that this friction is a complete loss, and that at least 35 horse-power loss is continuous as long as the engine is running, regard-

less of the number of floors operating. By testing each floor by means of a motor, it was found that from 50 to 60 percent of the power was consumed by friction of line shafting on these floors, making the total friction loss, with all floors operating, from 60 to 70 percent of the engine output.

Quarter turns are frequently required for machines standing at right angles to the main shafting, or for machines in wings of buildings. These are effected by means of positive universal joints or by belts. Universal joints cause a loss of from 10 to 20 percent, and the loss with quarter-turn belts is even greater, since both friction and slipping are encountered.

The space occupied by shafts, pulleys and belts is often valuable, and practically all of it can be made available for manufacturing purposes or for storage if motors are used. A motor can nearly always be set under a machine, or hung on the wall or a post or the ceiling, or placed in some corner where it is out of the way.

Lost motion always occurs in belt transmission. In one system of this nature with a combination of vertical transmission and many quarter turns, tests showed that the engine shaft made three revolutions before the shafting at the end of the transmission began to move. The speed of the shafting in the upper stories was also found to be ten percent low; that is, shafts intended to run at 200 r.p.m. were making about 180 r.p.m. The installation of electric motors nearer the machines, or better, on the machines, would cause a gain in production of ten percent by merely preventing this lost motion, since the machines are automatic, and their output is directly proportional to their speed.

The services of an engineer and fireman are always required where a boiler plant, engine, and mechanical transmission system are employed. For any except very small plants the whole time of one or more employees is required, and their wages should be included in calculating the expense of operating mechanical drive. With motors very little attention is required; often no more than the janitor, with a little instruction, is able to give.

In small shops a considerable amount of overtime work is frequently necessary, and the proper grouping of motors and machines is an important factor in economic operation. With individual or small group drive, only those machines actually required need be considered, whereas with engine drive the line shafting of the entire shop with its high friction losses must be kept running, perhaps for the sake of only a single machine.

The following example illustrates clearly the advantage of properly grouping the motor-driven machines.

Example I—A shop was driven by a single 25 horse-power motor with an average recorded load of ten kw. The various machines in the shop were subsequently divided into separate motor-driven groups without attempting to improve the arrangement of counter-shafts. The grouping and results obtained are shown in Table I.

The two groups of lathes are operated 14 hours per day; hence, when the shop was driven by a single motor the total energy required was $10 \times 14 = 140$ kw-hrs. When group drive was installed only 106 kw-hrs were required, that is, the saving is 34 kw-hrs per day. Assuming the power rate at three cents per kw-hr,

TABLE I—GROUP DRIVE

Groups of Machine Tools	Motor		Operation	
	H P Rating	Kw Load	Hours per Day	Kw-Hrs Per Day
Lathes	3	2	14	28
Lathes	3	2	6	12
Drills and Lathes	3	2	14	28
Milling Machine	3	2	9	18
Planer and Milling Machine .	5	2	10	20
Total	17	10		106

and 25 working days per month, the saving effected by the small group drive is $0.03 \times 34 \times 25 = \$25.50$, or \$306.00 per year, a large percentage of the total operating expenses of a small shop.

Many of the disadvantages of steam drive as compared with motor drive are of the kind that are not self evident and the saving that may be obtained by installing motors is often not realized until an investigation is made. The following example, giving the results recently obtained in an actual installation, affords a fair basis of comparison of the two systems, as the character of the manufactured product was not changed, and, consequently, the operating conditions were the same in both cases.

Example II—The engine-driven belt transmission originally employed in a small machine shop manufacturing brass fittings, was replaced by an up-to-date motor drive and electric power purchased from a local central station. The character of the manufactured

product was not changed, consequently the operating expenses before and after the substitution of electric drive afford a fair basis of comparison of the relative merits of the two systems. The original equipment consisted of a 12 horse-power steam boiler and a small engine driving the line shafting. A man, who tended the boiler and engine and did some other work, was employed for $2.50 per day; $1.50 of this amount was fairly charged against the operation of engine and boiler. The coal bill amounted to $25.00 per month. The boiler was discarded and the engine replaced by a 7.5 horse-power electric motor, with the result that the total power bills now range from $37.00 to $42.00, averaging approxmiately $40.00 per month. The yearly expenses for power with engine and with motor drive were as follows:—

ENGINE DRIVE	
Coal per year (12 × $25.00)	$300.00
Attendant (312 days at $1.50 per day)	468.00
Total	$768.00
MOTOR DRIVE	
Power bills (12 × $40.00)	$480.00
Difference favoring motor drive	$288.00

A 7.5 horse-power motor costs approximately $200.00 that is, the motor saves more than its first cost every year, thereby paying dividends of over 100 percent. Excepting the few repairs necessary, this saving goes on during the life of the motor, which is ordinarily many years.

The depreciation of engines and boilers is much greater than of electrical equipment, and moreover, to insure safe and reliable operation, the normal working pressure of the boiler must be gradually reduced from year to year, thus cutting down the plant capacity when, under normal conditions of business growth, it should be increased. This depreciation necessitates the periodic renewal of boiler equipment, and then is the time to consider electric motor drive. The following instance is a case in point:—

Example III—The boiler plant of an engine-driven factory devoted to the manufacture of nuts, bolts, screws, etc., had been gradually reduced to a safe working pressure of only 75 pounds. The business demanded more power than could be obtained under these conditions from the 50 horse-power engine, and new boilers were necessary if steam engine drive was to be continued. The question arose as to whether it would be cheaper to install new boilers and

retain the engine drive, or discard the old equipment and install motor drive throughout the factory and purchase power from the local central station, which was ready to furnish power. In case motors were installed, the following equipment would be required at an approximate total cost of $1 200.00:—

Polishing room	7.5 hp—1 200 r.p.m.
Tool room	15 hp—1 200 r.p.m.
Group of milling machines	7.5 hp—1 200 r.p.m.
Group of automatic machines	10 hp—1 200 r.p.m. 10 hp—1 200 r.p.m. 10 hp—1 200 r.p.m.

The cost of a suitable new boiler would be approximately $1 600.00, and assuming the cost of wiring, motor installation and accessories to be $400.00 in addition to the cost of the motors, the cost of the motor and boiler equipment would be approximately the same. The average load for the entire factory is about 25 kw, and the price paid for central station service on this basis is three cents per kw-hr. Assuming 25 working days of ten hours each, the relative costs per month of steam and electric power are then as follows:

Coal for steam plant per month	$140.00
Engineer's salary per month	90.00
Total	$230.00
Electric power $(0.03 \times 25 \times 10 \times 25)$	187.50
Difference favoring motor drive per month	$ 42.50

This monthly saving amounts to $510.00 per year, from which must be deducted the small cost of fuel for running a boiler to give low-pressure steam required in the factory. This type of boiler requires very little attention and can ordinarily be operated by the janitor.

As a matter of fact, however, the capital invested in motors, installation, wiring, etc., would be less than indicated by the foregoing, because the scrap value of the old engines, boilers, etc., should be deducted from the cost of the electrical equipment. And the cost of operation of the steam plant would be increased by the cost of oil, water, and other miscellaneous supplies, which have not been considered, but which frequently form a considerable expense.

SHOPS OPERATED BY TENANTS

In manufacturing plants where a number of shops are in one building and power is furnished the tenants by the owner, overtime

work is one of the most important considerations to the tenant. In a steam-driven shop, no tenant can work overtime unless the engine and whole mechanical transmission system is running. However important his work may be, the expense for power nearly always makes overtime work impractical. If such work is unavoidable the tenant can fairly be expected to pay the additional expense of operating the power system, and this is usually out of all proportion to the work done. Motor drive enables the tenant to operate his machines whenever it seems to his advantage to do so, and his power charge is only in direct proportion to the work done.

In some cases, tenants renting shops with steam power have found it profitable to install one or more motors for overtime work only, with arrangements such that their machines can be driven either from the main power system or from their own motors. In such cases central stations usually charge higher rates, as for breakdown connections.

Ownership of Motors—In rented shops equipped with motor drive, the motors may be the property of the tenants or of the owner of the building. Each tenant owning his motors must have an employee who is competent to make such periodic inspections and repairs as may be necessary. In his cost of operation must be included (*a*) interest and depreciation on investment in motors, (*b*) cost of inspection and repairs, and (*c*) cost of electric energy consumed.

Most central stations base their unit charges for energy on the amount consumed; that is, large consumers get lower unit rates than small consumers. These differences in rates often make it economical for the owner of the building to supply motors and care for them, charging each tenant the regular central station rate for the energy he consumes, the owner himself receiving the benefit of the lower wholesale rate from the station. Thus each tenant is relieved of the foregoing items (*a*) and (*b*) in cost of operation, and the central station is relieved of the meter reading, bookkeeping, etc., involved by dealing with a number of small consumers. The owner is well compensated for assuming these additional duties and expenses by the difference between the wholesale and retail rates for energy. Most of the additional duties can be performed by help which the building would require for other purposes, and such duties entail very little additional expense.

Example IV—Suppose a manufacturing building is occupied

by five tenants whose power requirements and costs at the prevailing central station rates are as shown in Table II.

The owner of the building can own the motors and the necessary meters with an investment of approximately $1 400. The rate to a single customer for the consumption of 15 725 kw-hr per month is 2.3 cents. Assuming that the motor inspections, meter reading, bookkeeping, collecting, etc., will add $10.00 per month to the regular expenses for care of building, the account of the landlord for power supply will be as follows:—

TABLE II—ELECTRIC POWER IN RENTED SHOPS

Tenant	Motor hp	Av. kw-hr. per month	Rate Cents per kw-hr.	Av. Monthly Bill
No. 1	15	2 500	3.3	$ 82.50
No. 2	20	4 300	3.2	137.60
No. 3	10	1 875	3.7	69.38
No. 4	30	6 350	2.9	184.15
No. 5	5	700	5.0	35.00
Totals	80	15 725		$508.63

Annual receipts from tenants, $508.63 × 12 = ...		$6 103.56
Annual cost of inspections, repairs, etc., 10 × 12 = ...	$ 120.00	
Interest (6%) and depreciation (10%) on investment ($1 400).	224.00	
Energy, 15 725 kw-hr. per month at 2.3 cents—per annum.	4 340.00	4 684.00
Net annual profit to landlord............................		$1 419.56

The total investment in motors, meters, etc., is returned to the landlord in one year, besides paying all interest, depreciation and labor charges. The tenants have no reason to complain, since they have paid the landlord the same amount that they would have paid the central station, and they have not invested any capital in motors, nor have they been required to care for them, as would have been the case if they had dealt directly with the power company.

SOME INTERESTING FEATURES IN THE DESIGN AND APPLICATION OF TRANSFORMERS

E. G. REED

THE service requirement for small transformers is that they have the best characteristics for a given price or, in other words, from the commercial standpoint, a minimum price for given characteristics. The losses are fixed largely by the costs to the central station of electrical power and transformer capacity. These efficiency requirements for small transformers are in contrast with those for large units, where the losses are usually secondary to price. This results in the larger transformers being built to secure the greatest output for a given amount of material. In this case, the flux density in the iron and the current density in the copper usually become the limiting factors of design. These limits are fixed by the saturation of the iron and the heating of the copper, the problem being one of making a transformer having a minimum loss for these densities.

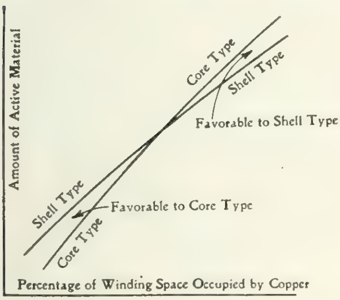


FIG. 1—RELATIVE VALUES OF TRANSFORMER TYPES, WITH DIFFERENT PERCENTAGES OF COPPER IN THE WINDINGS

These curves indicate, in general, that small high-voltage transformers should be made core type and large low-voltage units, shell type.

TRANSFORMER TYPES

The two distinctive types of transformers, "shell" and "core" type, have corresponding well marked portions of the total transformer field to which they are respectively best adapted, assuming that in a particular case either would be built for the same insulation strength. On analysis it is found that the factor which fixes the design as to type, is the space-factor of the winding; that is, the percentage of the total winding space occupied by copper. The space not occupied by copper is that required for insulation or for ventilating ducts. An idea of the relative values of the two types can be obtained by comparing the amount of material required to obtain certain electrical characteristics with a given space-factor, as shown in Fig. 1. This space-factor may be anywhere between the limits of a winding consisting of practically all insulation on

the one hand and solid copper on the other. If a comparison of the two designs were made on the basis of equal material for the two types, their relative values would be indicated by a difference in performance and the conclusions would be the same as before.

The curves show that there is a point where the values of the two types become equal. With better space-factor, i. e., increase in the percentage of copper in the winding, the shell type finds its best field, while with decreasing percentage of copper in the winding the core type asserts its advantage. Since small high-voltage transformers have a large percentage of insulation and large low-voltage designs a large percentage of copper, the curves indicate that the former should be made core type and the latter shell type. To show this, it will suffice to point out that the core type is in-

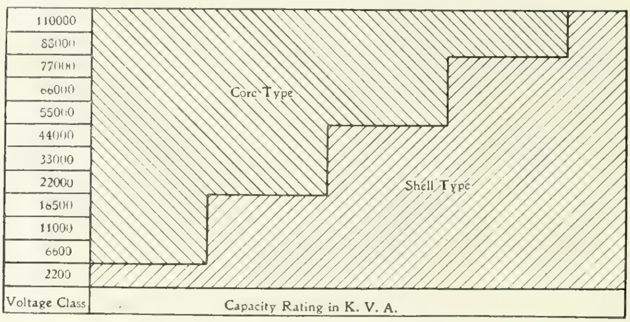


FIG. 2—ECONOMIC RANGE OF SHELL AND CORE TYPES OF CONSTRUCTION FOR THE DIFFERENT VOLTAGE CLASSES

herently light in iron and heavy in copper, while the opposite is true of the shell type. This means that the core type, being heavy in copper, has relatively the greater winding space; hence, with insulation clearances corresponding to a given voltage, the better space-factor represents an increased percentage of active material. It follows, then, that in each voltage class there is a space-factor corresponding to a certain output, above which the shell type and below which the core type is best adapted. The dividing line is shown in Fig. 2. Aside from these considerations, for mechanical reasons, the shell type is preferable for large units.

Independent of the question of space-factor, the core type construction is at present better suited for small transformers above 2 200 volts, mainly on account of its being better adapted for bringing out the high-tension leads. A small core type transformer is shown in Fig. 3. Setting aside the question of leads, if the space-

factor for 6 600 volts and higher could be made the same as for 2 200 volts, the improved shell type construction* could be used for these voltages with as good results as to efficiency.

The relation between the amounts of material required for transformers of the several types for 2 200 volt service, and for capacities not exceeding 50 kilovolt-amperes, is shown in Table I, the figures being based on equal losses for the three cases. The table shows that the space-factor of the core type transformer is six percent better than for the other two. Putting it on the same basis as the others in this respect, its weight become approximately 92 percent. These figures now represent the relative values of the three designs on the same basis as to space-factor. Comparing all three transformers on a lower space-factor would bring out the merits of the core type; or, in other words, a comparison of this kind for 6 600 volts or higher would show the core type of construction as better adapted for small sizes.

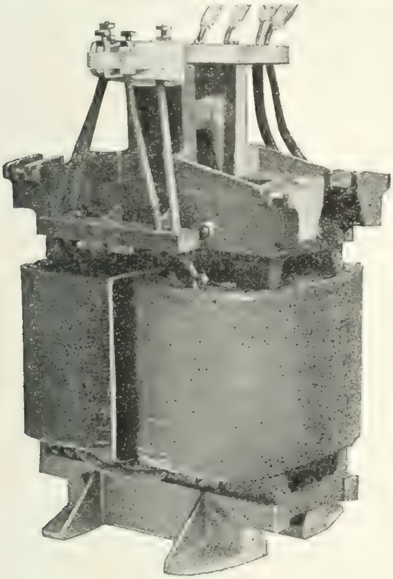


FIG. 3—SMALL CORE TYPE TRANSFORMER

TABLE I—COMPARISON OF TRANSFORMER TYPES FOR 2 200 VOLTS AND CAPACITIES OF 50 K.V.A. AND BELOW

Component Elements	Improved Shell Type, Percent	Simple Shell Type, Percent	Core Type, Percent
Weight of iron.........	100	97	67
Weight of copper.......	100	117	136
Total weight............	100	103	87
Space-factor of winding*	100	100	106
Volume†	100	90	70

*The space-factor of the improved shell type transformer is arbitrarily called 100 percent and that of the others expressed as a percentage of this value.

†The volume in this table is the volume of the coils and magnetic circuit without the case.

*See Fig. 9, p. 401, May, 1910.

MAGNETIC CIRCUIT

The ideal magnetic circuit for a transformer would be one composed of iron of high permeability, while the other extreme would be a circuit of air only. As joints are introduced into the iron circuit, its characteristics approach those of an air circuit whose permeability is unity. Curve *A*, Fig. 4, which shows a sharp knee at about 12 000 lines per square centimeter, is the magnetization curve for a magnetic circuit of iron without joints. Curve *D* is the magnetization curve for an air magnetic circuit. As shown, the magnetization curves of the iron circuits eventually approach a straight line, parallel to the air line, in which case the permeability of the

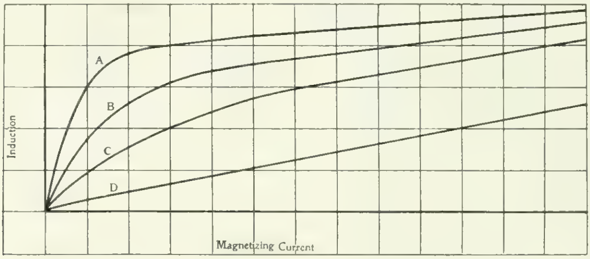


FIG. 4—MAGNETIZATION CURVES OF TRANSFORMER MAGNETIC CIRCUITS

Showing variation of magnetizing current required to give a certain induction in the iron circuit under various conditions. *A*—Magnetic circuit consisting of sheet steel laminations without joints. *B* and *C*—Showing effect of increase in number and change in relative position of joints. *D*—For magnetic circuit of air only.

iron approaches but does not reach unity. Curves *B* and *C* show the effect of increasing the number and varying the relative positions of joints in the laminations. As the air-gaps increase, the knee of the magnetization curve is gradually reduced and disappears finally when the straight line for air is reached. It will be noted that curves *A*, *B*, and *C* have a common starting point (zero), and the difference between them increases gradually up to the saturation point, or at the knee of the upper curve, and decreases gradually again at the higher inductions. Hence, it is only under the condition of relatively high induction that an iron circuit with joints can be magnetized to a degree equal to that possible with a circuit involving simply solid laminations. Also, to obtain a degree of induction on curve *B* or *C* corresponding to that of a point at or below the knee on curve *A*, a larger magnetizing current is

required. It is, therefore, important that the number of joints be as small as possible and that they be placed at the most advantageous locations.

If the magnetic circuit is composed of two or more parts in parallel which do not have the same relative sectional areas at all points, cross-fluxes will be set up where the relative areas change, and, as these cross through some of the laminations, eddy currents are produced which increase the iron loss. The eddy currents in the plates have a tendency to force back this flux, thus preventing an extremely large loss. However, some loss must result from the presence of these currents.

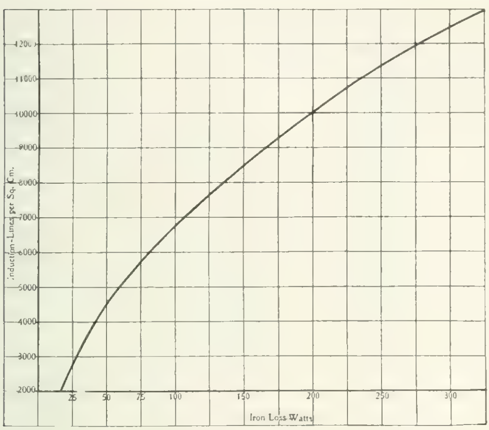


FIG. 5—INDUCTION-IRON LOSS CURVE

With transformers so designed and so operated that the iron is worked at a density below the knee of the magnetization curve the iron loss will be found by test to increase approximately as the 1.7 power of the induction or impressed voltage.

While the characteristics of the copper windings of a transformer are practically constant and change very little with the different units of the same design, the magnetic element is variable in its behavior. To obtain uniformity in the iron loss it may sometimes be found necessary in case of high iron loss to dismantle the unit and substitute new iron.

When a transformer on test does not come up to expectations as to iron loss and the trouble is not traceable to the quality of the iron, it must be caused by some extraneous element, such as:—circulating currents in the windings; laminations not properly enameled; mixture of two or more qualities of iron of different permeabilities; magnetic cross-flux. The careful elimination of such points as these is necessary to get low and uniform iron losses with the modern grades of iron.

Circulating currents may appear in the windings as a result of paralleling different windings which have slightly different ratios.

The unbalanced voltages causing these currents, and consequently the currents themselves, will increase directly as the induction in the magnetic circuit. Hence, the loss due to these currents (i^2r loss) will increase as the square of the induction. Eddy currents between laminations will also introduce an element of loss which increases as the square of the induction. A considerable amount of eddy current loss is evidence that the laminations are not sufficiently insulated. Losses of the nature described above will increase the iron loss throughout the entire range through which the induction is carried, i. e., the exponent of the iron loss curve* will

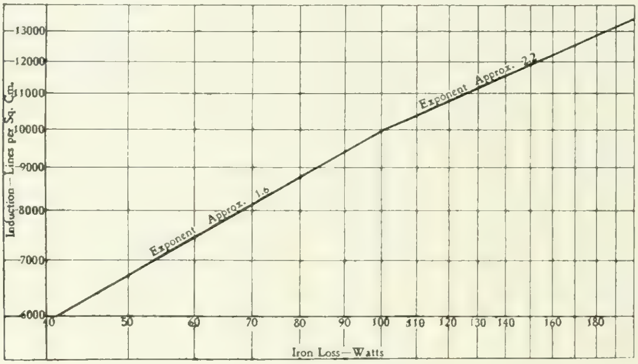


FIG. 6—TRANSFORMER IRON LOSS CURVE CORRESPONDING APPROXIMATELY TO FIG. 5 PLOTTED TO LOGARITHMIC COORDINATES

When thus plotted, a curve such as that of Fig. 5 becomes a straight line of definite slope. If the iron loss varies at a different rate than the 1.6 power of the induction as the voltage is increased, this fact will be indicated by a change in the slope of the straight line. Thus abnormal iron loss may be detected.

be increased. If the exponent changes materially within a range of induction from zero to 15 or 20 percent above normal value, the inference is that a cross-flux exists, or that two kinds of iron of different permeability have been used. The exponent due to these troubles within a range of normal inductions is not to be confused with the increase in the exponent which sometimes appears

*An iron loss curve is one plotted between voltage impressed on the transformer or the resulting induction in the magnetic circuit as ordinates and iron loss as abscissae. This curve will take the form shown in Fig. 5. Each value of the loss may be expressed as being equal to the product of a constant times the induction raised to a certain power, say, the 1.7 power; i.e.,

$$\text{Loss} = \text{constant} \times (\text{Induction})^{1.7}$$

In this case the loss is said to vary as the 1.7 power of the induction, and the quantity 1.7 is called the exponent of the iron loss curve.

at high inductions. This latter change is due to a great increase in the hysteresis component of the loss, which in some cases may result in the total loss increasing as the third or fourth power of the induction. If the magnetic circuit is made up of two kinds of iron, which have different permeability characterstics, the flux will seek the iron of high permeability and thus increase the loss very greatly in that portion.

In order to determine the value of the exponent of the iron curve for a transformer, and to see at a glance if the exponent changes throughout its range, the logarithm of the induction and the logarithm of the iron loss values may be plotted instead of the direct values of these quantities, or, what is equivalent, direct values of induction and iron loss may be plotted on logarithmic coördinates.* If the logarithmic curve thus plotted is a straight line, the exponent is constant, and is equal to the slope of the line. If the line curves, the exponent changes at the point of curvature. This is shown in Fig. 6, in which the curve is composed of two straight line sections of different slope.

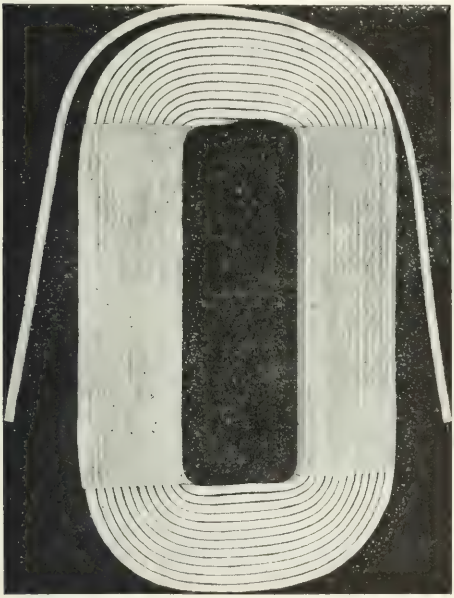


FIG. 7—SECTION-WOUND COIL FOR LARGE TRANSFORMER

Example of coil which receives varnish rather than the impregnation treatment.

IMPREGNATION

The practice of impregnating coils has been extended until a considerable percentage of all windings made receive this treatment. Windings composed of either sandwiched or concentric coils consisting of a number of layers having many turns per layer,

*Logarithmic coördinates may be laid off conveniently from one of the scales of an ordinary slide rule.

or the so-called wire wound coils, are impregnated. On the other hand, large shell type transformers using section wound coils such as shown in Fig. 7, i. e., flat pancake coils with one turn per layer, are not ordinarily given this treatment. Coils of the latter type are thoroughly dried and receive several coats of baked varnish. This sort of insulation, which secures high disruptive strength without the use of tape and similar material, is ideal for the dissipation of heat. This is important where the copper is working at fairly high current densities.

On high-voltage, wire-wound coils, where very high insulation strength is required, the windings are first impregnated and then wound with successive layers of tape, which may in turn be impregnated or varnished, as the case may require, see Fig. 8.

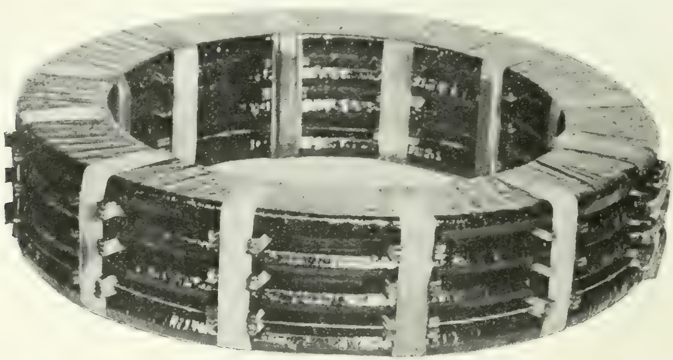


FIG. 8—IMPREGNATED COILS FOR HIGH-VOLTAGE CORE TYPE TRANSFORMER

After impregnation the outside surface of each coil is covered with taping which in turn is varnished or impregnated; an effective means of reinforcing the insulation.

The cotton covering on the wires used in transformer windings serves as a spacer only, and to secure sufficient insulation strength to meet service conditions the use of an impregnating compound of high dielectric strength is required. This and the fact that the compound cements the wires in place and helps to conduct heat out of the coils are, in brief, the reasons for its use.

The materials forming the base of the oil-proof impregnating compounds are resinous gums, combined in such a way as to give the required melting point and penetrating power. Either excretions from gum trees or fossil gums are used in connection with other materials of a similar nature.* With an oil-proof compound of

*See "Impregnation of Coils with Solid Compounds," by Mr. J. R. Sanborn, in the JOURNAL for March, 1910, p. 195.

satisfactory dielectric strength, the problem of impregnating becomes largely one of penetration. Many factors must be considered, such as temperature, pressure, vacuum and the condition of the compound to get the proper degree of penetration.

Another point which must be carefully looked after is to see that the air which is forced into the tanks in driving the compound into the coils is perfectly dried before entering.

FAILURE IN SERVICE

The term "burn-out" is commonly used in connection with transformers which become inoperative and must be removed from service. They may be literally burned out or be injured by abnormal conditions, such as, for example, a short-circuit. An examination of burned out transformers extending over a number of years shows that there are two main causes for such failures, viz., short-circuiting and roasting by overload. The development of an actual short-circuit in a transformer in service, say in the high-tension winding, causes a large current to flow in the short-circuited part. The short-circuited portion, acting as a secondary carrying a large current, draws an abnormally large current through the remainder of the primary winding. Thus, a short-circuit starting in the primary winding may or may not spread throughout the entire coil, depending on the way the transformer is protected by fuses. When a short-circuit develops in the primary winding, practically destroying it, the secondary coils are likely to remain in fairly good condition. In this way, it is usually possible to distinguish between a short-circuit starting in the primary winding and a general roast-out by overload. If the short-circuit starts in the secondary wind-

FIG. 9—TRANSFORMER BURNED OUT BY SEVERE OVERLOAD

When roasted by continued excessive heat, the entire insulation becomes charred and brittle, and loses its insulating properties.

ing, the trouble is likely to be localized in that part, and the primary coils may or may not be injuriously heated. In cases of failure in transformers of the larger sizes, the trouble is usually localized, indicating a short-circuit due to water, lightning or some such cause, and the transformer is cut out by the protecting device before the trouble has extended through the winding.

Conditions similar to those caused by water or lightning may result from the wires working against each other when the windings expand and contract under varying conditions of load. Short-circuits caused by defective winding of the coils may be due to rough, imperfectly welded joints, to improperly insulated wires, or to extreme pressure or pounding of the insulation. In their manufacture, all transformers are given an over-potential test at from two to three times normal voltage to locate just such troubles. Those faults resulting from defective winding are detected by the factory tests and such transformers are never allowed to go into service.

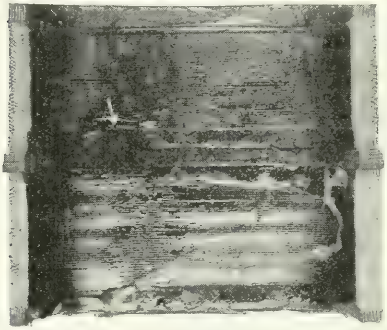


FIG. 10—SECTION OF PRIMARY COIL OF TRANSFORMER SHOWING BREAK-DOWN DUE TO SHORT-CIRCUIT DEVELOPED BY WATER

Such a break-down is distinguished by the local character of the trouble. If continued in service the transformer will eventually be completely destroyed as in the case of excessive overload.

There is one class of short-circuits known as "high resistance short-circuits," which are sometimes rather mystifying. They show up as a high iron loss, and it is at times difficult to determine whether the trouble is due to defective winding or bad iron. Such a short-circuit may clear itself after the transformer is loaded. This is done by the expansion of the coil and consequent separations of the wires which were very nearly in contact. The short-circuit can usually be developed and located by an over-potential or overload run.

A record of cases of burn-outs developing in transformers of the smaller capacities shows that about 65 percent of them failed from overload, 20 percent from water and 15 percent from short-circuit due to lightning and various other causes. In cases of overload the windings are reduced to a mass of copper wire and charred insulation. For distributing trans-

formers the conditions of service are such that failures from overload are likely to occur. Since the maximum load exists for only a few hours daily the tendency is to increase the maximum value of this load beyond safe limits, the transformer accordingly being fused to such an extent that several times the normal current is required to blow the fuse. For example, the smallest fuse-wire obtainable is No. 36, 18 percent German silver, which melts with one ampere. This would mean a load, at 2 200 volts, of 2.2 k.v.a. The smallest fuse-wire ordinarily used on any transformer is No. 26, which fuses at 7.5 amperes or 16.5 k.v.a. at 2 200 volts. Such a load continued for any length of time would inevitably burn out a transformer of lower output than 7.5 k.v.a. An examination of the records show that practically 80 percent of the all burned-out transformers returned to the manufacturers are below 7.5 k.v.a. capacity.

Transformers burned out as a result of water trouble are ordinarily found to be so completely soaked that there can be no mistake about the cause. Other failures may also be traced to moisture as the primary cause. Doubtless, some water gets into the transformers by the so-called breathing action, which continually takes place with changes in load. Trouble from this source is especially prevalent in damp localities. In order to prevent this as far as possible, impregnated gaskets are placed between the case and the cover, particularly in the higher voltage transformers. The lead outlets are also sealed with a compound similar to that used in impregnating the coils. At the bottom of transformer cases a small plug is provided to permit of the removal of water which has settled under the oil. A regular oil plug, about one inch in diameter, is also provided. In addition to the moisture acquired through this breathing action, a transformer may get it with the oil. Oil stored in drums and not protected from the rain may take up water.

A burn-out from overload, such as usually occurs on small transformers, roasts the whole winding uniformly, as shown in Fig. 9. A short-circuit, started from moisture, produces a local failure, as shown in Fig. 10. The two photographs were made from windings actually burned out under such conditions.

SUMMARY

In discussing the question of transformer types, it has been shown that large low-voltage units should be built shell type and small high-voltage transformers core type. The dividing line in

each voltage class comes at larger and larger sizes as the voltage increases. Each class, therefore, has a perfectly legitimate field and neither is adapted for universal application. This matter has been gone into at length in order to put upon a clear and definite basis a question much discussed during recent years.

In a comparison of transformers that have magnetic circuits without gaps with those having magnetic circuits made up of a number of segments and different relative positions of the gaps, the very great importance of carefully studying these points is apparent. Since the effect of the number of joints and their position becomes most important at the point of saturation, the most advantageous positions must be secured. These facts, together with many others, must be considered in order to get the best results with modern grades of steel which, while giving a lower iron loss, are more prone to eccentric behavior. Extreme care is required in connection with both the design and application of transformers to get low and uniform results from a given quality of iron.

Impregnation of transformer windings is now quite general, and the successful operation of modern transformers is largely due to the improved quality of the gums used. The absolute necessity of uniform penetration and thorough drying have been emphasized.

Examination, through a number of years, seems to indicate that overloading is the most prolific source of trouble with distributing transformers. A lesser number become short-circuited due to moisture, lightning, etc., and a few fail from defects having no adequate explanation. The conditions of service on small transformers are such that burn-outs from both overload and moisture are not only possible but in reality normal under average central station practice.

WINDING OF DYNAMO-ELECTRIC MACHINES—III

SMALL INDUCTION MOTORS

SKEIN WOUND TYPE

G. I. STADEKER

FOR small alternating-current work the single-phase induction motor with split-phase starting winding is quite generally used. Its windings are simple and inexpensive. Its characteristics are such that it is readily adaptable to almost all classes of work to which small machines are applied. It can be built for any commercial frequency and phase, and for any ordinary industrial voltage.

Polyphase motors are inherently self-starting. Single-phase motors require some special starting device. In small motors this nearly always takes the form of a special starting or "teaser" winding, which with the main winding produces a rotating field. The main winding consists of a great many turns of relatively heavy wire. Consequently, its inductance is high compared with its resistance, and its power-factor at the start is correspondingly low. In the starting winding the wire is comparatively light and of high resistance. The resistance is, therefore, the predominating characteristic in this winding, the power-factor is correspondingly high, and the currents in the two windings are out of phase by a considerable angle. A rotating field is thereby produced similar to that in a two-phase machine, although the currents are not separated by as great an angle as in a two-phase circuit.

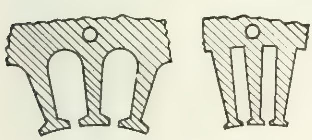


FIG. 41—STATOR SLOTS

The relative number of turns of main and starting winding depends on the design. If the machine is designed for a high starting torque, the wire in the starting winding will be comparatively large and will have a lesser number of turns. If it is to have a starting clutch, so as to start without load, more turns of finer wire will be used. The electrical characteristics, and the size of wire in the starting windings may thus vary greatly in two machines of the same rated horse-power and speed.

THE CORE

The stator core is built up of laminated punchings, with slots similar to one of those shown in Fig. 41. They are assembled

directly on the supporting bolts, which serve to give exact alignment of the slots. End plates of fullerboard or fiber are used to furnish insulation between the core and the windings. The punchings and end plates are compressed by a screw in a special jig, and the nuts on the bolts are tightened to hold the core in compression.

WINDING A SINGLE-PHASE STATOR

A long skein of wire, such as shown in Fig. 42, is wound on an adjustable form, the length of the skein and the number of turns of wire it contains depending on the number of coils per pole, and the number of turns per coil specified. For convenience in handling,

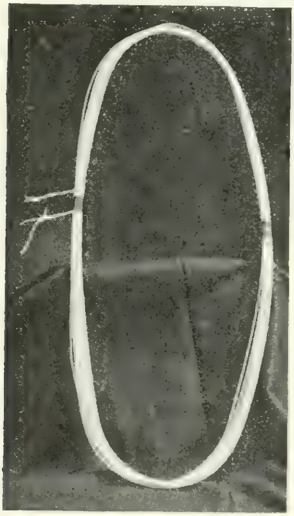


FIG. 42—WIRE SKEIN
These skeins vary from 27 to 115 inches perimeter.

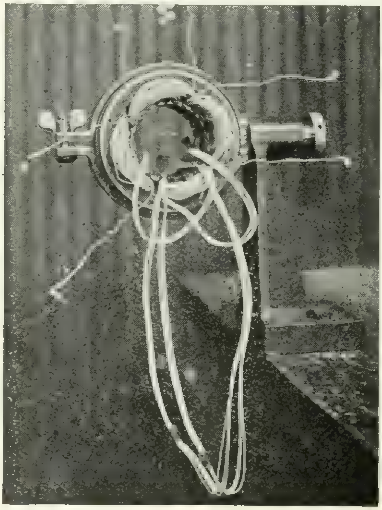


FIG. 43—PARTLY WOUND STATOR
Showing method of inserting skeins.

the core is mounted in a yoke, as illustrated in Fig. 43. The slots are insulated with a fisn-paper protecting cell and a treated cloth cell, with projecting edges.

The method of winding is very simple. Assume, for instance, a four pole, single-phase winding, a core having 24 slots, and the diagram shown in Fig. 44. The skein is inserted into slots *3* and *5*, and its end pulled tight against the insulating end plates. The long loop is then crossed on itself, and reinserted in the slots, the side which was in slot *3* going into slot *5* and vice versa. The skein is then looped back and forth according to the diagram. The last two slots

into which the skein is inserted have only half as many turns as the others, since part of the adjacent skein goes into these slots also.

The length of skeins for motors of this kind is, of course, considerable in order to make so many convolutions, ranging from 115 to 27 inches in perimeter for the main windings and from 96 to 27 inches for the starting windings, for motors under one horse-power. If there are a number of turns, the skein may be divided after the first loop is in place, and each division wound separately. Fig. 43 shows a skein thus divided into three sections, one of which is being looped back through the core. The lower division is threaded through first and the others in succession. Great care should be exercised to make the loops lie straight and even in the

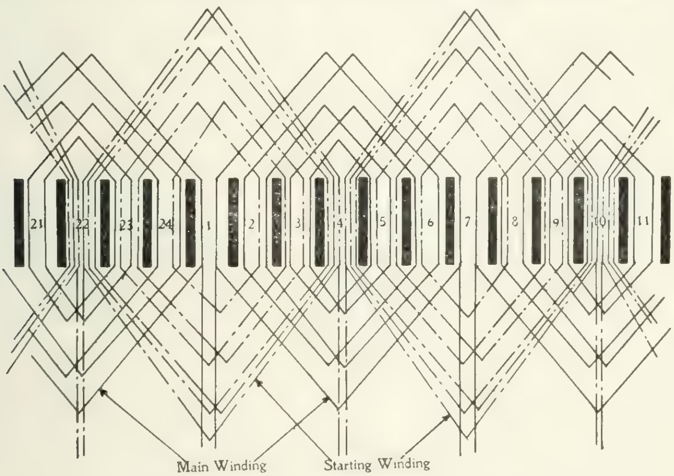


FIG. 44—WINDING DIAGRAM FOR SINGLE-PHASE STATOR

slot, without twisting, as otherwise all the wires will not enter the slot, and the insulation is liable to be damaged. When a skein has been completely wound, the cells are trimmed and folded in. The other skeins are wound in a similar manner, there being one skein per pole.

The starting winding is formed from skeins of smaller wire than the main winding. Slots *4*, *10*, *16* and *22* have no main winding, and are insulated with fish paper and treated cloth cells to protect the starting winding which completely fills them. The other slots have an extra cloth cell inserted over the main winding to enclose the starting winding which goes into the same slots, as shown by the diagram, and is wound in the same way as the main winding. After all the slots have been filled the coils are forced

into position with a fiber drift, the cells are folded in and a fiber wedge inserted in each slot.

The coils of each winding are all connected in series, according to the connection diagram, Fig. 45. The leads of the starting winding are interrupted, as shown in Fig. 46, by the circuit opening device. The two circular stationary segments are insulated from each other and from the frame and are mounted side by side on the bearing housing. At the start they are short-circuited by the rotating shoes which close the circuit of the starting winding until the speed reaches the point at which centrifugal force throws them off. This is ordinarily at about half speed.

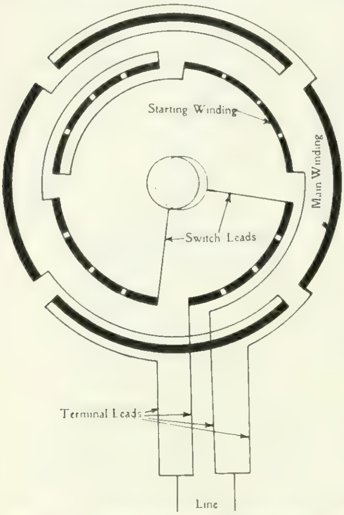


FIG. 45—CONNECTION DIAGRAM FOR SINGLE-PHASE STATOR

The end connections of the main and starting windings are separated by friction cloth. They may be taped or not, according to the specifications. Fig. 47 shows the completely wound stator.

The windings are tested for grounds with the standard high voltage test of 1 000 volts for one minute. Each winding is tested for short and open circuits by applying alternating current through a wattmeter. An excessive reading indicates a short circuit, while no reading shows an open circuit. Polarity is tested by applying direct current to the windings and testing with a compass. Adjacent poles should attract opposite ends of the needle. If the windings are correct, the end connections are dipped in a quick drying plastic varnish, which serves not only as an insulating medium, but excludes all dust and serves to stiffen the windings and make them moisture proof. After dipping they are thoroughly dried in an oven. The main and starting windings are connected in parallel, usually outside the machine. The direction of rotation is determined by the way the connections are made. To reverse interchange the two starting leads.

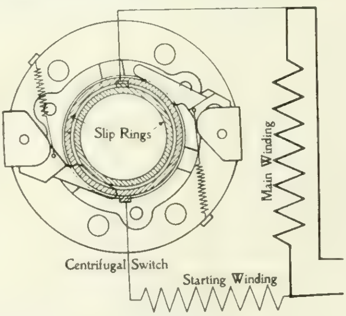


FIG. 46—CENTRIFUGAL SWITCH CONNECTIONS

POLYPHASE MOTORS

While the great majority of small alternating-current motors are single-phase, there is some demand for polyphase motors. The method of winding is very similar to the winding of a single-phase motor. The slots are insulated with fish paper and treated cloth cells, and the skeins, which are in this case similar, are inserted into the slots in accordance with the winding diagram, which will be similar to the one shown in Fig. 48 or 49, for three-phase or two-phase respectively. Each skein or group of coils overlaps the preceding one at the ends, as shown in Fig. 50, the ends of the coils being separated from one another by a layer of treated cloth. To

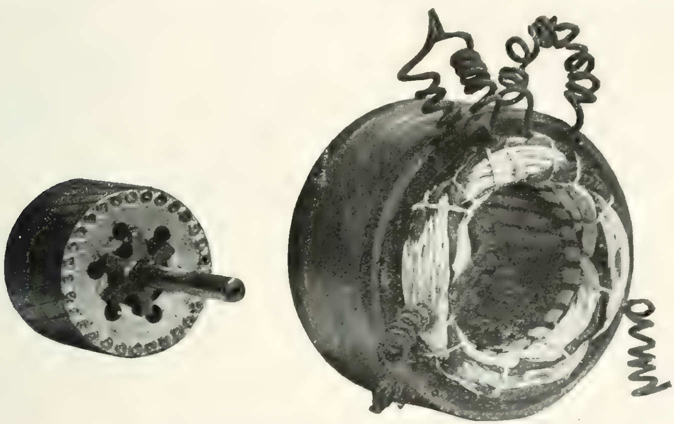


FIG. 47—COMPLETED SINGLE-PHASE WINDING
Rotor and stator.

produce a symmetrical winding, it would be necessary to remove half of the first skein before the last one was put in place, in order to make them overlap in regular order. As the electrical characteristics of the machine would not be changed by so doing, the last skein is allowed to overlap two skeins, while the first skein is overlapped by two others. The skeins are connected according to the connection diagram shown at the right in Figs. 48 and 49. The connections determine the phase and polarity of the machine. For instance, an armature having twelve skeins or groups of coils, can be connected for six poles, two-phase, or eight poles, three-phase.

No starting winding is required for polyphase machines, and since they have a good starting torque there is no need for a friction clutch on these machines. They are tested for breakdown between phases, and from each phase to ground, and for short and open circuits, as described for single-phase machines.

THE ROTORS

The rotors of these small machines are of the squirrel cage type. The laminations have slots of one of the types shown in Fig. 51, the round form being in more general use. In assembling the rotor, the proper weight of punchings is roughly assembled over the shaft of a suitable jig, with a tinned copper end plate at each end. The

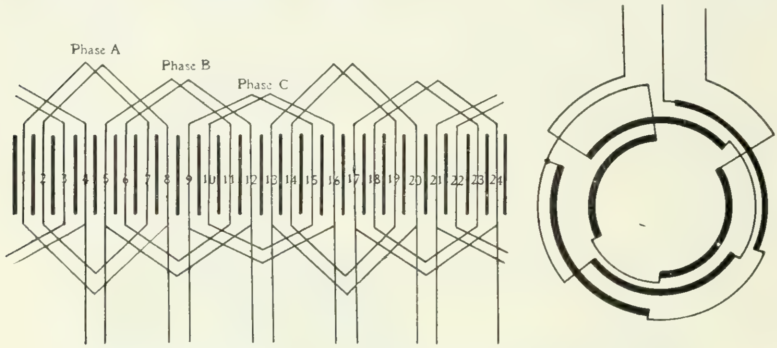


FIG. 48—WINDING DIAGRAM FOR THREE-PHASE STATOR

slots are then aligned by driving a steel rod through one of the slots, and by inserting several of the copper bars at intervals around the rotor. These bars fit loosely in the slots and serve to approximately line up the punchings. The core is then partly compressed by the screw in the jig, accurately aligned by driving a tight fitting

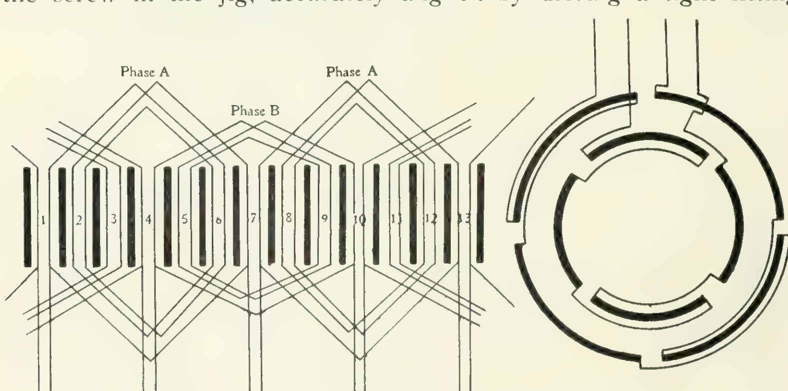


FIG. 49—WINDING DIAGRAM FOR TWO-PHASE STATOR

steel drift into the slot openings, and at the same time is skewed the width of one tooth by twisting the steel rod the required amount. The core is then completely compressed by the jig. The copper bars, which are drilled to a slight depth at each end, are inserted into all the slots, and firmly riveted with a center punch and hammer, which

expands the metal, and makes close contact with the end plates. The ends of the bars are then cleansed with a soldering flux, and the rotor is dipped into melted solder, the solder uniting the whole into a compact unit, but not adhering to the iron, which is always slightly oily.

With slots of the form shown at the right in Fig. 51, bars of rectangular cross section are used. These bars have a slit sawed in each end. After the core has been compressed in the jig, the split ends are spread by means of a chisel, and the core is transferred to a hydraulic press where it is further compressed between dies, which are specially shaped to rivet the ends of the bars into close contact with the end plates.

FIG. 50—COMPLETED THREE-PHASE WINDING

The completed rotor is pressed on a spider, as shown in Fig. 47. If a friction clutch is used for starting without load, the spider fits loosely on the shaft so as to rotate freely. The clutch consists of an iron ring of rectangular cross-section divided into three segments, which are held together by springs. This is attached to the spider and is mounted inside a clutch case which is rigidly fastened to the shaft. The rotor starts up without load by rotating on the shaft, until the centrifugal force in the clutch overcomes the spring tension, when the segments fly out, making a friction contact on the inside of the clutch case sufficient to start the load. The speed at which the motor picks up its load can be adjusted by changing the spring tension in the clutch.

FIG. 51—ROTOR SLOTS

If no friction clutch is to be used the spider is pressed tightly on the shaft, and the rotor is ready for mounting in the frame. Metal distance pieces, fitting loosely on the shaft, are used to keep the rotor correctly centered with reference to the stationary winding.

DATA ON ELECTRIC RAILWAYS

THE tables given below contain quite complete data on the various railway electrifications both in this country and abroad for the direct-current, single-phase and three-phase systems as installed by the various American and foreign electrical manufacturers. The first six tables are from appendix II and appendix IV of the paper by Mr. George Westinghouse on "The Electrification of Railways." This paper was published in condensed form in the July issue of the JOURNAL.

DATA ON ELECTRIC LOCOMOTIVES OF AMERICAN DESIGN*

The locomotives on which data are given were built for heavy railway service. They are for passenger service and for combined passenger and freight, and include locomotives for direct current, three-phase current, and single-phase alternating current, and others adapted for operation on either freight, and include locomotives for direct current, three-phase, alternating current, and single-phase alternating current, and others adapted for operation on either single-phase alternating current or direct current. A brief description of these locomotives follows, including mention of some of their notable features.

LOCOMOTIVES OF THE WESTINGHOUSE ELECTRIC & MFG. CO.

Referring to Table I, the first column covers locomotives built for the New York, New Haven & Hartford Railroad, for operation on their electrified zone between New York and New Haven. The electrical system demanded that the locomotives be capable of operation both on single-phase and direct current. There are 41 of these locomotives in operation. A gearless concentric motor for each driving axle is mounted on a quill flexibly connected to the driving wheels. The dead weight on the axles is thus reduced to a minimum.

The second column covers locomotives built for the Grand Trunk Railway for operation in the St. Clair Tunnel under the St. Clair River. These locomotives are designed for operation with single-phase current only. They are handling the entire freight and passenger traffic through the tunnel.

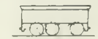
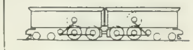
The third column covers locomotives built for the Pennsylvania Railroad for operation in their New York tunnel. They are for passenger service only and operate on direct current at 600 volts on the conductor. The first locomotive has been run 17 000 miles on test. The center of gravity of these locomotives is high, as the motor is mounted well above the driving axles. The transmission from motor to wheels is by cranks and connecting rods. These parts are protected from possible damage due to short-circuit by interposing between the armature and its shaft a friction clutch which will slip before damaging stresses are imposed on the transmission. The motors are the largest railway motors ever built and are provided with commutating poles, making possible the use of a shunted field control which is applied to these locomotives.

The fourth column covers a locomotive built for the New York, New Haven & Hartford Railroad for use in high speed freight and medium-speed passenger service. It also is fitted for operation both with single-phase and direct current. It has been run approximately 3 000 miles in test service, actually hauling regular freight trains, including the steam locomotives, over the electrified section of the railroad on the normal schedules for the movement of these trains. A pinion at each end of the motor meshes with a flexible gear whose center is rigidly secured to the quill surrounding the axle, the flexible gear overcoming the difficulties in securing tooth alignment and division of load which are liable to occur when rigid twin gears are used. It is

*From an appendix to the paper by Mr. George Westinghouse on "The Electrification of Railways."

TABLE I—DATA ON ELECTRIC LOCOMOTIVES OF AMERICAN DESIGN

BUILT BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

					
Built for	New Haven	Grand Trunk St. Clair Tun'l	Pennsylvania	New Haven	New Haven
Electric system	A.C.-D.C.	A.C.	D.C.	A.C.-D.C.	A.C.-D.C.
Service	Passenger	Frt. & Pass.	Passenger	Frt. & Pass.	Frt. & Pass.
First placed in service	July, 1907	February, 1908	17 000-mile test	3 000-mile test	building
No. in service or on order May, 1910	41	6	24	1	1
No. motors per locomotive	4	3	2	4	2
Armature diameter, inches	39½	30	56	39½	76
Core length, including vent opening, inches	18	14¾	23	13	13
Weight one motor, pounds	16 420	15 660	45 000	19 770	41 600
Weight all motors on locomotive	65 680	46 980	90 000	79 080	83 200
Weight all electrical parts	110 400	58 400	127 200	130 000	135 000
Weight all mechanical parts	94 100	73 600	204 800	130 000	125 000
Weight complete locomotive	204 500	132 000	332 000	260 000	260 000
Weight on driving wheels	162 000	132 000	207 800	180 000	180 000
Weight complete locomotive for A.C. operation	196 000	132 000	D.C.	241 000	240 000
Max. guar't'd speed, miles per hr	about 86	30	about 80	45	45
Feature limiting speed	track	armatures	connecting rod	armatures	armatures
Max. tractive effort	19 200	43 800	69 300	40 000	40 000
Loco. wt. in excess of 18% adhesion Max. T.E., A.C. operation	88 700	none	none	18 500	17 500
Designed for trailing load, tons	250	500	550	1 500 freight 800 pass.	1500 freight 800 pass.
Balance speed on level with above load	about 75	about 25	60	35 freight 45 pass.	35 freight 45 pass.

the only electric locomotive equipped with spur-geared motors which are bolted rigidly to the spring-supported parts of the locomotive. Each driving wheel is driven through helical springs, the arrangement being such that the driving wheel has practically free vertical play. The locomotive has two trucks, the draw-bar pull being transmitted through the truck frames. The body is spring-mounted on friction plates in place of being carried on track center pins in the usual manner. It is an exceptionally easy riding machine with very low rolling friction. The performance has been satisfactory, and a speed of 40 miles per hour was attained on level track with a 1 600 ton train.

The fifth column covers a locomotive for the same railroad and service as that just described. The comparison between geared and connecting rod motors for identical service is a very interesting feature of this development. The weights given in both the fourth and fifth columns are those on which locomotives of these types would generally be built. The actual locomotives are somewhat heavier, due to particular features of design not inherent in the type. The effect of the pulsating torque of a single-phase current on the connecting rods and pins is avoided by the introduction of a flexible connection between the armature and its shaft. This locomotive has not been tested. These last two locomotives were ordered by the New Haven road to demonstrate the practicability of electric traction for freight service and to assist in determining the most suitable kind or type of locomotive.

LOCOMOTIVES OF THE GENERAL ELECTRIC COMPANY

The first column of Table II covers locomotives built for the New York Central & Hudson River Railroad for operation on the electrified zone of the New York City terminal. Forty-seven of these locomotives are in use, the first having been put in operation in July, 1906. They are used for passenger service only, and operate on direct current at 600 volts. The mechanical equipment of this locomotive consists of a main driving wheel base with four driving axles and a four-wheel guiding truck at either end. The motor is of the bi-polar gearless type, the armature being mounted directly on the driving axle, and the mechanical structure of the locomotive forming a portion of the magnetic circuit of the motors. The characteristic feature of the locomotive is the simplicity of its electrical and mechanical construction, which contributes to its high efficiency and low maintenance cost.

The second column of Table II covers locomotives built for operation at the Detroit River Tunnel. These are to be used for both freight and passenger service between Detroit, Mich., and Windsor, Ont., and will be operated at 600 volts, direct current. The running gear consists of two trucks connected together with a massive hinge so as to form a single articulated wheel base, and buffers carried on the outer end frames of the trucks. The motor is of the direct-current geared type with commutating poles and is interesting as the first application of the commutating pole motor to this class of service. Twin gearing is used between the motor and driving axle, and consists of a pinion at each end of the armature shaft and a corresponding gear on the axle. The use of twin gearing relieves the armature shaft of torsional strains and maintains the parallelism of the shaft and axle. Five of these locomotives have been built and are awaiting completion of the tunnel. While they are not in actual operation, extensive tests made on a test track in hauling and accelerating freight trains up to 1 500 tons in weight have proved that this type is very satisfactory for the service.

The third column covers locomotives built for the Baltimore & Ohio Railroad for operation of both freight and passenger service through the Baltimore Belt Line Tunnel. Two of these locomotives are in use and operate on direct current at 600 volts. The general design is similar to the Detroit Tunnel locomotive described above and the same type of motors are used, but the motors are geared for higher speed in order to meet the speeds required by passenger service on the relatively lighter grades of the Baltimore Tunnel.

The fourth column covers locomotives built for the operation of freight and passenger trains through the Cascade Tunnel of the Great Northern Railway. These locomotives are designed for three-phase operation at 25 cycles

TABLE II—DATA ON ELECTRIC LOCOMOTIVES OF AMERICAN DESIGN

BUILT BY THE GENERAL ELECTRIC COMPANY

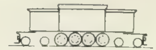
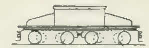
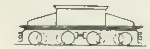
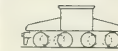
					
Built for	N.Y.C.&H.R.R.	Detroit River Tunnel	B. & O. R. R.	Great Northern	Paris-Orleans
Electric system	D.C.	D.C.	D.C.	3-phase	D.C.
Service	Passenger	Frt. & Pass.	Frt. & Pass.	Frt. & Pass.	Passenger
First placed in service	July, 1906	tests completed	March, 1910	July, 1909	1899
No. in service or on order May, 1910.	47	6	2	4	11
No. motors per locomotive	4	4	4	4	4
Armature diameter, inches	29	25	25	35¾	23½
Core length, including vent. opening, inches	19	11½	11½	16¼	12
Weight one motor, pounds	18 150	10 560	10 560	15 000	8 855
Weight all motors on locomotive	72 600	42 240	42 240	60 000	35 420
Weight all electrical parts	91 200	54 000	54 000	109 000	42 500
Weight all mechanical parts	138 800	146 000	130 000	121 000	67 500
Weight complete locomotive	230 000	200 000	184 000	230 000	110 000
Weight on driving wheels	141 000	200 000	184 000	230 000	110 000
Weight complete locomotive for A.C. operation	D.C.	D.C.	D.C.	230 000	D.C.
Max. guar't'd speed, miles per hr	75	30	55	30	45
Feature limiting speed	track	armature	armature	armature	armature
Max. tractive effort	47 000	67 000	61 000	77 000	37 000
Loco. wt. in excess of 18% adhesion Max. T.E., A.C. operation	none	none	none	none	none
Designed for trailing load, tons					
Freight		900 on	850 on	500 on 2.2% grade	
Passenger		600 2% grade	500 1½% grade		
Balance speed on level with above load	435 / 63	Freight 20.5 / Pass. 22	Freight 26 / Pass. 30	15	300 / 32

TABLE III—SINGLE PHASE ELECTRIFICATIONS

ON STEAM RAILWAYS AND IN TRUNK LINE SERVICE

Road	Miles of Line	Miles of Single Track	Line Voltage	Motor Cars		Locomotives	
				No.	hp	No.	hp.
N. Y., N. H. & H. R.R. Main Line	21	100	11 000	4	600	41 2	1400 1600
New Canaan Br.	8	8	11 000	2	500		
Grand Trunk R. R.	3.5	12	3 300	...	...	6	900
Erie R. R., Rochester Div.	34	34	11 000	6	400	...	....
Colorado Southern Ry. Denver & Interurban	46	46	11 000	8	500	...	....
Baltimore & Annapolis Short Line	25	30	6 600	12	400	...	....
Swedish State Ry.	7	7	3 300 20 000	2	240	1	300
Midland Ry., England.	8.5	17	6 600	1 2	300 360	...	....
Prussian State Rys.	16.5	31	6 600	20 42 54	250 400 345	1	1500
London, Brighton & South Coast Ry.	8.6	17.2	6 000	16	460	...	....
Rotterdam-Haag-Scheveningen	20.5	46.5	10 000	19	360	...	....
Spokane & Inland	129	129	6 600	28	400	6 5	500 720
Midi Ry. of France	75	...	12 000	30	500	2	1600

TABLE IV—DIRECT-CURRENT ELECTRIFICATIONS

ON STEAM RAILWAYS AND IN TRUNK LINE SERVICE

Road	Miles of Line	Miles of Single Track	Line Voltage	Motor Cars		Locomotives	
				No.	hp	No.	hp
New York Central R. R.	33	132	650	137	400	47	2200
Pennsylvania R. R.	20	75	650	180	400	24	4000
West Shore R. R.	44	106	650	20	360	..	....
Long Island R. R.	42	125	650	137	400	2	1200
West Jersey & Seashore R. R	75	150	650	68	400	..	....
B. & O. R. R.	3.7	7.4	600	...		2.5 5	1600 1100
Northeastern Railway	37	...	600	...	300	2	600
Mersey Tunnel	4.8	...	600	24	400	..	....
Lancashire & Yorkshire Ry.	18	60	600	...	600	..	....
Great Western Ry.	5	...	600	...	600	..	....
Metropolitan Railway	...	67	600	56	600	10	800

TABLE V—CAR EQUIPMENT OF SUBWAY AND ELEVATED SYSTEMS IN AMERICAN CITIES

THE DIRECT-CURRENT THIRD-RAIL SYSTEM AT APPROXIMATELY 600 VOLTS IS USED IN ALL CASES

Road	Miles of Single Track	Motor Cars	
		No.	hp
Boston Elevated Railway	19	219	320
Brooklyn Rapid Transit	71	558 101	300 400
Interborough Rapid Transit (New York)	190	969 764	250 400
Hudson & Manhattan (New York)	12	140	320
Chicago & Oak Park	19.4	65	320
Metropolitan West Side (Chicago)	51.1	15 210	400 320
Northwestern Elevated (Chicago)	25.5	20 128	250 320
Southside Elevated (Chicago)	36.5	150 70 150	180 150 110
Philadelphia Rapid Transit	11	100	250

TABLE VI—THREE-PHASE ELECTRIFICATIONS

ON STEAM RAILWAYS AND IN TRUNK LINE SERVICE

Road	Miles of Line	Miles of Single Track	Line Voltage	Motor Cars		Locomotives	
				No.	hp	No.	hp
Great Northern R. R.							
Cascade Tunnel	4	6	6600	...	...	4	1900
Italian State Railways							
Valtelina Railway	66	...	3000	10	400	2 7	800 1500
Giovi Railway	12.4	37.3	3000	...	...	20	2000
Mt. Cenis Tunnel	4.4	...	3000	...	...	10	2000
Savona Ceva	...	...	3000	...	...	10	2000
Swiss Federal Railways							
Simplon Tunnel	13.7	14.3	3000	...	...	2 2	1100 1300
Gergal Santa Fe (Spain)	13.1	14.4	5500	...	...	5	320

TABLE VII —DATA ON THREE-PHASE RAILWAYS IN EUROPE

Line	Type, Gauge and Length of Track (Miles)	Total Weight and Speed of Train (m. p. h.)	Kind of Current on Contact Line	Locomotives, No. and Type	MOTORS No. per Locomotive and Kind	MOTORS HP	Source of Power
BUILT BY BROWN, BOVERI & CO., LTD.							
Tramway Co., Lugano, Switzerland	Narrow Guage Council, 3.2 mi.	9 tons 9.3	400 V., 40 Cycles.	4–Two-Axle, Auto Motors	1–Slip Ring	20	Council Electric Works, Lugano
Gornergrat Ry. Co. Switzerland.	Rack, 3.281ft., 5.8, mi., Zermatt to the Gornergrat	Up to 28 tons 4.5	500 V., 40 Cycles	3–Cog Wheel (Rowan Suspen'n)	2–Slip Ring	90 Rated	Hydro-Electric Power Station
Jungfrau Ry. Co., Switzerland	Rack, 3.6 mi. from Scheidegg to the Jungfrau	Up to 34 tons 5	650 V., 40 Cycle	5–Cog Wheel*	2–Slip Ring	150 Rated	Hydro-Electric Power Station at Lauterbrunnen
Stansstad Engelberg Ry. Co., Switzerland	Adhesion and Rack, 14.3 mi. From Stansstad to Engelberg	Up to 28 tons 3.1 and 7.2	750 V., 32 Cycles	2–Cog Wheel 5–Four-Axle, Closed Type Auto-Motors 2–Open-Type Auto-Motors, 46 Seats	2–Slip Ring 2–Slip Ring Each Auto-Motor	75 Rated 35 Rated	Hydro-Electric Power Station at Obermatt
Burgdorf Thun Ry. Co.	Standard, 25.2 mi.	Freight, up to 130 tons, 11.2 and 22.4 Passenger, up to 50 tons, 22.4	750 V., 40 Cycles	2–Two-Axle, 30 ton 1–Four-Axle, 42 ton 6–Four-Axle Auto-motors, 65 seats	2–Slip Ring 2–Four-Speed, Squirrel Cage 4–Slip-Ring	150 Rated 250 Rated 60 Rated	Hydro-Electric Power Station (Kander Works)
Tramway Co., Schwys Seewen, Switzerland	Narrow Guage, Section Gotthard Ry., 1.2 mi.	12 tons 9.3	500 V., 40 Cycles	3–Two-Axle. Auto-motors, 36 seats	2–Slip-Ring	25 Rated	Hydro-Electric Power Station on Muotta River
Simplon Tunnel Swiss Federal Rys. △	Trunk Line Standard, 14.3 mi.	Passenger, up to 350 tons, Freight, up to 650 tons 21.8 and 43.6	3000 V., 15 Cycles	2–3/5-Axle 2–4/4-Axle	2–Two.Speed, Slip-Ring 2–Four-Speed, Squirrel Cage	550 Rated 650 Rated	Co's., Electric Power Sation at Brig and Iselle
Gergal Sante Fe, South Spain, Ry. Co.	Trunk Line 5.5 ft. 14.4 mi.,	Freight up to 350 tons, 7.8 and 15.6	5500 V., 25 Cycles	5–Two-Axle, normally coupled in pairs	2–Squirrel Cage	160 Rated	Steam Power Station at Sante Fe
Rheineck Loop Line, Ropeway Co., Rheineck Walzenhausen, Switzerland.	Loop Line, Standard, 0.75	16 tons, approx. 10	500 V., 50 Cycles	1–Two-Axle Auto-motor	1–Slip-Ring	28 Rated	Hydro-Electrie Power Station above sub-station at Rheineck

BUILT BY GANZ & CO., BUDAPEST.							
Evian les Bains		9.7 m. p. h.	500 V	2 Tramcars.	2-With Rheostat control.	12	
Woellersdorf, Ammunition W'ks			3000 V.	1	1	50	
Valtellina Ry., Soc. della Ferrovie Meridionali △	Standard 65.8 mi.	Up to 500 tons 20 and 40	3000 V., 15 cycles	10-Auto Motors. 2 3 4	2-H. T. & 2—L. T. 4-H. T., In. Parallel 2—Double H. T. & L. T. Parts. 1-Eight pole 1-Twelve-pole	200 200 750 1500 1000	Hydro-Electric Power Station at Morbegno.
BUILT BY SOCIETE ITALIANA WESTINGHOUSE							
Giovi Ry., Italian State Rys. △	Trunk Line 37.3 mi. btw. Genoa and Busalla.	Up to 500 tons 28	3000 V., 15 cycles	20-Ten coupled wheels, each.	2-H. T.	1000	Italian State Ry's Steam Power Station, Two Turbo—Generators, 5000 Kw Each.X
Mont Cenis Tunnel, Italian State Rys.	Standard 4.3 mi. btw. Bardonecchia and Modane.		3000 V., 15 cycles	10-Ten coupled wheels, each.	2-H. T.	1000	Hydro-Electric Power Station of City of Turin, at Chiomonte.†
Savona Cena, Italian State Rys.	Trunk Line		3000 V., 15 cycles	10-Ten coupled wheels, each.	2-H. T.	1000	Hydro-Electric Power Station at Ventimiglia; Steam Reserve Station, Savona.‡

* Brown, Boveri & Co., Ltd., have supplied three locomotives and one 800 hp. Generator.

△ See article on "European Three-Phase Railways" by Mr. R. E. Hellmund, in the JOURNAL for May and June, 1910, pp. 359 and 484.

X Plant erected; capacity will be doubled soon by addition of two duplicate sets.

† Plant in course of erection; the State Railways are studying project for power station at Oulx for purpose of extending electrification to Turin.

‡ Plant in course of erection; the State Railways will procure current from the Societe Negri.

and 6 600 volts on the trolley. The mechanical structure consists of an articulated wheel base similar to that of the Detroit River Tunnel locomotive described above. The motor is a three-phase induction motor with external secondary resistance and fitted with a gear at each end of the armature shaft. The service for which they are ultimately designed is the operation of a division 57 miles long with ruling grades of 2.5 percent and an average grade of 1.55 percent.

The fifth column covers locomotives built for the Paris-Orleans Railway, for use in hauling passenger trains from the Austerlitz Station to the Quai d'Orsay. They are designed for operating on 600 volts, direct current. These locomotives are historically of interest, the first one of them having been delivered in 1899, and twelve being now in service. Each locomotive has two independent trucks, each truck equipped with two geared motors, and carrying weight of cab and platform on the center pin with draft gear and buffer attached to this platform. This represents a type of locomotive of which a large number have been built, and which has proved highly satisfactory for light and medium classes of service.

ELECTRIFIED STEAM ROADS AND ELECTRIC ROADS FOR TRUNK LINE SERVICE*

The accompanying tables, III, IV, V and VI, give data upon many of the important railroads on which electricity is used in heavy railway service. Only such data are included as were conveniently available and such omission or inaccuracies as may occur do not detract materially from the forceful presentation of the extent and character of the use which is now being made of electricity in railway service.

The horse-power rating of the various motor cars and locomotives are in general the nominal ratings for a short period, usually one hour, but as these ratings have been adapted in some cases to the particular service in which the motors are to operate they cannot be taken as a basis for an accurate comparison between the capacities of different equipments.

*From an appendix to the paper by Mr. George Westinghouse on "The Electrification of Railways."

THREE-PHASE RAILWAY INSTALLATIONS IN EUROPE

Table VII, which has recently been prepared from authoritative sources, contains a list of the three-phase railway installations in Europe. This table is not a part of the paper by Mr. Westinghouse. While the list appears quite formidable it will be seen on inspection of the table that a considerable proportion of the installations are quite small.

EXPERIENCE ON THE ROAD

A SIMPLE REMEDY FOR STATIC ERROR IN METERS

WILL C. BAKER

A TROUBLE that may arise in connection with measuring instruments is that due to accidental electrification of the glass window, arising, for example, from cleaning the glass by rubbing it with a dry cloth or with one's fingers. The resulting static attraction on the needle may cause it to give false indications. Suppose that, either accidentally or in cleaning, the window of a meter has become electrified, no matter to what degree. Although the charge will dissipate itself in a reasonable length of time and thus disappear, it may be completely neutralized in a moment by simply passing a lighted match or any small source of heat back and forth in front of the glass at a distance of about an inch. Neither the flame or hot gases need be brought nearer than that distance, and this only for a moment, so that there is no necessity for smoking nor even appreciably heating the glass.

This simple remedy depends upon the property, possessed by flames, of "ionizing" the surrounding air. The theory of this action may be stated briefly as follows:—The property of conducting electricity, possessed in varying degrees by various solids, liquids and gases is explained as being due to the presence of a greater or less number of so-called positive or negative "ions" which have the power of carrying corresponding charges of electricity. The action of the flame is to break up the air immediately surrounding it into positive and negative ions, thus temporarily increasing the number of free ions present in the air, and thereby increasing its conductivity in proportion. Applying this to the present case, the flame of the match serves to increase the ionization of the air adjacent to it, whereupon the static charge on the glass draws from this ionized air sufficient free ions of opposite charge to produce complete neutralization, thus putting an end to the effect of static attraction on the needle of the meter. There is no possibility of electrifying the window of the meter with an opposite charge by the use of this method. As the ions move downwards or horizontally, or in any direction with equal ease it is not necessary to set the instrument upright to de-electrify the glass.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

468—Fly-Wheel Effect—Please explain the meaning of the term "fly-wheel effect" and also what use is made of it in the design of fly-wheels and revolving fields of alternators. W. F. M'K.

The term "fly-wheel effect" is used to denote a quantity proportional to the amount of inertia of the fly-wheel. It represents the summation, for various parts of the fly-wheel, of the products of weight multiplied by the square of the radius at which that weight is situated. The fly-wheel effect is generally expressed in "lbs. at one foot radius," the weights being taken in lbs. and the radius in feet. In the case of a fly-wheel carrying most of the weight in a shallow rim the fly-wheel effect is nearly equal to the weight of the rim multiplied by the square of the mean radius of the rim in feet; or, in general for rough work, the total weight of the fly-wheel, multiplied by 0.16 multiplied by the square of the outside diameter in feet, may be taken as the fly-wheel effect. There is a corresponding quantity for the rotating field of the alternator which is generally added to that of the fly-wheel itself to give the combined fly-wheel effect. The total fly-wheel effect required in any case depends upon the required uniformity of rotational velocity; and, where parallel operation is required, it is usual to specifv for the prime mover driving the alternator a limiting value for the angular displacement of the rotor at any point of the revolution from the position in which it would be at the same instant if the rotation were entirely uniform. The relation between the necessary fly-wheel effect and the above requirements is largely an engine problem, but is also influenced by the fact that an alternator load is not a dead load as in the case of a water brake, but that the instantaneous torque required to drive the alternator varies with the above mentioned displacement when the machine is running in parallel on a bus-bar; in other words, the combination of an alternator paralleled on a bus-bar and a fly-wheel is similar to a weight on the end of a spring in having a natural period of oscillation of its own, which period can be verified by a variation of the total fly-wheel effect. It is, therefore, necessary to ascertain that the fly-wheel effect proposed does not give a natural frequency of oscillation which nearly approaches the frequency of any forced impulse introduced by the engine itself or otherwise, and to thus avoid the possibility of resonance and the consequent large swings that will gradually be produced by even insignificant impulses. See notes by Mr. P. M. Lincoln on "Fly-Wheel Effect," "Engine Requirements," and "Table of Maximum Permissible Variations," in the JOURNAL for Dec., 1906, p. 678. A. B. F.

469—Installation of Railway Signal Circuit—It is proposed to run a two-wire lead-covered cable underground and parallel to a considerable length of track, to supply alternating current to operate signal mechanism. It has been argued that fairly good results may be obtained by placing the cable in a creosoted wooden trough, and filling it with pitch, the cable, of course, being kept from the sides and bottom while the trough is being filled. A heavy lid will then be nailed on the top. Voltage on cable to be 3 300 volts. If this does not seem practicable, please suggest some other plan. The cable should be put underground in order to have it comparatively free from lightning troubles. As

the line would extend over quite a number of miles, the work must be as cheap as possible.

C. E. G.

If the question is one of relative merits of lead-covered cable installed in the ground without further protection as against running a twin conductor cable without lead covering in pitch, inside a wooden trough, it may be stated that the latter method would undoubtedly prove to be the better, because the lead sheathing very soon disintegrates when laid in the earth without other protection. This is especially true in locations where the chemical constituents of the earth are such as to destroy the lead, or where trouble may be expected from electrolysis. It is a very common practice to run low voltage wires imbedded in pitch, in the manner specified in the question. However, a steel tape armored cable could be more highly recommended for the above service. This cable would have a bedding of jute around the lead, over this two steel tapes, and over the steel tapes another bedding of jute saturated in tar. In spite of the rugged construction of a cable of this kind, it may still be injured by men working with pick-axes or other such implements and so would not be guaranteed as fully as would cables laid in a well constructed conduit system. As an example of the view taken by the engineer of the N. Y., N. H. & H. R. R., it may be stated that they have gone to the expense of running a cable in terra cotta conduit lined with fibre conduit. Where so much depends on the reliability of the system, as is the case with alternating-current signal mains, no conclusion should be arrived at as to the best method of installing them, without carefully considering the local conditions under which they are to be installed, the kind of insulation to be used and the detail methods of bringing the cables out of the ground to the various pieces of apparatus to which they may be connected. The matter of drainage enters very largely into the consideration. It is thus obvious that specific cases demand the attention of a competent engineer who is thoroughly familiar with all the conditions.

L. F. H. & H. W. F.

470—Use of Spare Alternator for Improving Power-Factor — In a factory being equipped with 440 volt, 60 cycle, three-phase motors there is a 75 kw, 440 volt, three-phase belted type alternator which will not be needed as a source of power, as current will be supplied from a plant about 2000 feet distant. The motor equipment will aggregate about 440 hp in motor sizes from three hp to 75 hp. The alternator is provided with an auxiliary winding; accordingly it may be operated as a self-starting synchronous machine, using simply an ordinary auto-starter. With this starting arrangement it will start up in this way under about 30 percent load. Direct-current will be supplied for field excitation from the exterior set. It will probably have an all day load of from 30 to 75 hp. Are there any objections to this arrangement? What will be the effect on the power-factor and will the gain in this respect more than compensate for the use of apparatus more complicated than an induction motor for the particular load that it is proposed to handle by means of this machine, or would it be advisable to exchange it for an induction motor?

F. H. E.

The subject of power-factor correction has been quite comprehensively covered in articles and Question Box items as noted in the Six Year Topical Index, p. 12, and the following items: Nos. 366, 410, 425, and 426. No complication will be involved in the proposed use of the spare alternator. The alternator will have an effect of raising the power-factor of the load, the amount being dependent on the various operating conditions involved. The determination of this effect may be readily made by the method given in the above references. The improvement in power-factor will have no direct effect on

the operation of the motor load; it will, however, increase the effective capacity of the circuit and thus improve the voltage regulation at the load. It will also materially improve the operating conditions so far as the generators at the power station are concerned, especially if the motor load in question represents a considerable percentage of the generator load. Because of the relatively large corrective effect required as the power-factor approaches unity it is rarely found economical to attempt to raise the power-factor above 90 percent. Ordinarily in industrial work a synchronous motor installed for purpose of power-factor correction should preferably be operated with the maximum field that it will safely carry in order to obtain at all times the maximum corrective effect. Thus, its field should not be under the control of any automatic regulator. In starting a synchronous machine its field should be short-circuited until it has attained maximum speed, operating as an induction motor with full line voltage applied. The field circuit is then immediately connected to the direct-current exciting circuit, whereupon the machine operates as a sychronous machine. A double pole, double throw switch should be used for facilitating this step in the operation of starting, the field circuit being connected to the two middle points of the switch, the two outside points of one side of the switch being short-circuited and the two outside points of the other side of the switch being connected to the exciting circuit. The connection to the autostarter and to the field switch are given in No. 305. S. N. C.

471—Difficulty with Parallel Operation of Transformers—In a substation there are two banks of step-down transformers operating in parallel. Each bank consists of three 200 kw single-phase units connected in delta and having a ratio of 30 000/2 300 volts. When the load, which consists of 2 300 volt, three-phase induction motors, is connected to any one of these banks separately, the three ammeters connected on the secondary side read the same. But when both of the banks of transformers are thrown in parallel the two corresponding sets of meters read differently even without load on the circuit. Is it not possible that this is due to a wrong ratio in one of the transformers? If so, what would be its cause; also, how can the defective transformer be traced, and the trouble remedied? M. N. G.

It is evident that one or more of the transformers are operating with incorrect ratio. In order to determine whether two transformers, connected in parallel on both primary and secondary sides, have the same ratio, open one of the secondary connections and connect a suitable voltmeter between the terminals separated. If the voltmeter shows no deflection, the transformers have the same ratio. By testing all of the transformers in each bank in this way, the unit having the incorrect ratio can quickly be determined. The effect of having a transformer with incorrect ratio operating in such a bank is to introduce an unbalanced voltage in the bank, which gives rise to a "circulating" or "balancing" current. It is this current which manifests itself in the unequal indications of the respective meters when the transformers are operating with apparently balanced load. E. C. S.

472—Prevention of Syphoning of Oil in Transformer—We have experienced trouble due to syphoning action of the leads in some of our transformers, the oil running out of the tank and down the leads. What is the cause of this action and how can it be remedied? It has been found that the trouble arises only in the case of transformers of the older design. G. M. B.

This action is due to what is known as capillary attraction. The action is analogous to that of the wick of an oil lamp in drawing oil from the reservoir, feeding the flame of the lamp, and takes place both between the insulation and

and the conductor and between the strands of the conductor. After the flow is established it is perpetuated and augmented by a syphonic action of the leads outside of the case. To prevent the trouble it is usually sufficient to remove the insulation from the leads for a short distance above the point where they issue from the oil, at the same time soldering the conductor at this point so as to fill the spaces between strands. E. G. R.

473—Discoloration of Shellac—It is noticed that the effect of mixing shellac for armature winding with de-natured alcohol darkens the shellac, as compared with a mixture using regular wood alcohol. Is the former inferior in insulating qualities? Does not the change of color denote a chemical change? If so, is it not due possibly to the effect of the benzine used in making the de-natured alcohol? R. N. D.

We are not certain regarding the nature of the change when shellac turns dark; however, the insulating properties do not seem to be affected in any way. The only apparent reason why de-natured alcohol should have more effect on shellac than wood alcohol is that the latter commercial product probably contains a higher percentage of impurities. It consists of grain (ethyl) alcohol mixed with benzine. The grain alcohol may be made from many different materials; for example, refuse of various vegetable matter, corn stalks, etc. In the manufacture of alcohol from these materials, refining processes are not so carefully carried out as in the case of wood alcohol. It is possible to obtain de-natured alcohol of equal purity by stating specifically that such is required. J. R. S.

474—Apparatus for Filling Transformer Tanks with Oil—In the process of filling transformers with oil by first exhausting the air from the cases before introducing the oil, I would like to know, (*a*) How high a vacuum is necessary to give good results? (*b*) How high a vacuum is it generally possible to obtain in practice? (*c*) What type of pump is best suited for vacuum work for chambers containing not over several subic feet air space? F. T. S.

(*a*) A vacuum of at least 25 inches should be used. (*b*) It should be possible to obtain a vacuum of 27 inches. (*c*) Any make of simple single or double-acting plunger pump provided with a lever for operation by hand would probably be found satisfactory. W. N. C.

475—Protection from Lightning of Transmission Line and Cable Circuit in Parallel—A high-tension transmission line and a local power station serve as optional sources of power for a sub-station load. The sub-station is connected to the transmission line by several high-tension cables in parallel. It is connected to the local power station about 2000 yds. distant by means of 235 000 cir. mil. three-phase high-tension cable. The transmission station and power-station are further connected in parallel by means of two three-phase overhead lines of No. 00 copper to which a distributed load is connected, the majority of the latter being located nearer the local station. It is desired to do away with the operation of the latter plant, but then the voltage at this section of the circuit is too low; accordingly it is proposed to utilize the cables connecting the transmission lines and local plant via the sub-station to increase the line capacity to this main portion of the load and thus hold up the voltage. The cables will be connected to the overhead line through automatic switches, thus protecting them against overloads. At the paralleling bus-bars electrolytic lightning arresters are to be used to protect the cables against lightning and other disturbances. (*a*) Should choke coils also be used? (*b*) If so, should they be on the cable side of the bus-bars? (*c*) Are they not liable to be the cause of a resonant condition in the circuits? (*d*) If not

used, will the electrolytic lightning arresters give ample protection? A. C. R.

For this case the electrolytic or aluminum cell lightning arrester is to be recommended, but choke coils are not. It is true that high voltages may momentarily result and the tendency towards resonance from harmonics is increased by the use of choke coils in connection with cables. In addition any oscilation or disturbance in the cable is likely to be reflected at the cable end and a choke coil accentuates this tendency and is disposed to cause flash-overs at cable terminals and even punctures at a node at some other point. R. P. J.

476—Difficulty with Cummutator Brushes on Rotary Converter—We have three 1 500 kw and six 750 kw rotary converters in a railway sub-station and have experienced considerable trouble through the brushes on the negative arms becoming coppered while those on the positive arms become glazed and do not pick up copper. Wherein does the trouble probably lie? G. A. C.

Many converters of these capacities are in operation and are giving no such brush trouble The action referred to must be due to the local conditions, and may be traced either to excessive loads, inferior brushes, or wrong methods of brush lubrication. Note No. 347. The difference in action between the positive and negative brushes is one frequently noticed and is due to an electrolytic effect which results in the "picking up" of the copper referred to in the question. This electrolytic action is referred to in No. 336. F. D. N.

477—Comparative Safety of Grounded and Ungrounded Distribution Circuits—In a three-phase distribution system with potentials of 600 volts or less is it advisable to operate with the neutral point grounded or ungrounded? Assuming the worst possible operating conditions, viz., power distributing circuits in coal pits for operating cutters, which method introduces greater liabilities to shock? How is this affected by the following rule quoted from our British Rules for Electricity in Mines (Rule No. 7)? "In every completely insulated circuit, earth or fault detectors shall be kept connected up in every generating and transforming station, to show immediately any defect in the insulation of the system. The readings of these instruments shall be recorded daily in a book kept at the generating or transforming station or switch-house." What is the element of risk and at what point does the capacity effect become dangerous to human life? L. G. R.

In regard to comparative safety in a grounded or ungrounded 600 volt, three-phase system, the danger from shock would in general appear to be less with a system ungrounded. The rule quoted implies the requirement of some form of fault detector which, for the voltage in question, would doubtless consist of three lamps connected from each line to ground or voltmeters similarly connected. Unless the lamp or voltmeter connections are of very high resistance a virtual neutral ground is formed on the system and thus it is rendered practically as dangerous, as far as shocks are concerned, as though the system had a complete ground. This would not be the case if the voltmeter possessed sufficient internal resistance to limit its currents to 0.01 ampere or less. In other words, the resistance of this conductor should be high as compared with the probable resistance of a person making accidental contacts to the line. The capacity effect of the line would not be likely to materially increase the risk, unless metal sheathed cable were used; even then, the capacity would of course depend on the length of the cable employed. R. P. J.

THE

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The New York City Terminal of the Pennsylvania Railroad

Few, even among railroad engineers, realize the aid which the advent, in railroad motive power, of the electric locomotive has supplied in the solution of transportation problems heretofore impossible. A recent publication by the Pennsylvania Railroad, commemorating the completion of the magnificent New York City Terminal Station, recently formally opened and soon to be in general use, recites the history of the efforts of the management of that company to obtain a passenger station on the island of Manhattan.

This problem was first considered in 1871, when the United Railroads of New Jersey were leased, and has ever since occupied the attention of the most talented and experienced engineers. The use of a tunnel for standard railroad equipment was early considered, but given up as out of the question when steam locomotives were the only motive power available. In 1884 a proposition was entertained to build the "North River Bridge" with a span almost twice that of the Brooklyn Bridge, but the possible obstruction to navigation, enormous cost due to the great amount of valuable property on either shore which would be occupied and rendered useless, together with the impossibility of financing this undertaking, led to its abandonment. About this time also the general transportation problem within the city of New York was engaging the consideration of the best equipped minds in that field, and it was then and afterward proposed to built extensions and duplications of the existing lines of elevated railroad then operating by steam locomotives, but on a much more elaborate plan, involving inevitable depreciation in the value of enormous amounts of property, due to the nuisance of the operation of trains on such lines and the unavoidable darkening and obstruction of many streets and other public thoroughfares.

The successful development of the electric motor for traction purposes, first in comparatively small units applied to the car axles, and during the past decade in sizes so large and capacity so great as not only to equal, but in the case of the "Pennsylvania Locomo-

tive," so well described in Mr. Kirker's article, to exceed the power of any steam locomotive heretofore built, has now set forever at rest the thought of further damage and annoyance from steam locomotives in our great cities. It is the advent of an electric locomotive of large capacity and this alone that has enabled the Pennsylvania Railroad to finally solve the New York terminal problem, which for almost forty years was found impossible of accomplishment.

The great cost of this splendid terminal is often commented upon. The cost is great and yet when the manner of its accomplishment is considered, how marvellously economical is the method by which it has been done, as compared with any other possible means without the aid of electricity as a motive power. The value of land in the heart of New York City is so great and its use, without disturbance of the neighborhood, so paramount, that the establishment of the greatest railroad terminal in the world in the very center of this great metropolis, with the occupation of only the space required for the actual accommodation of the passengers served, is an achievement, not only epoch-making, but unique in the world's history.

Millions were spent in excavating the tunnels under two great rivers and removing the material under the city for the tracks necessary in this great terminal, whose capacity is one thousand trains per day, but the great buildings, other city property, avenues, streets and all means of communication, so valuable in a large city, remain absolutely undisturbed. There is also an entire absence of noise, noisome vapors or other nuisances usually incident to a railroad terminal, all conserving enormous values, and rendered possible only by the advent of the electric locomotive and the general use of electricity for power and light. E. M. Herr

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Adherence to Adopted Standards

The great value of intelligent standardization of manufactured products of all kinds is universally recognized. In no industry is this standardization of more importance than in the electrical industry on account of the diversity of the apparatus involved. Both the American Institute of Electrical Engineers and the Ameican Association of Electric Motor Manufacturers have endeavored to forward the standardization of electrical apparatus in this country by incorporating in their rules, what are considered to be characteristics of standard supply circuits and apparatus used in connection therewith.

Next in importance to the standardization of apparatus is the application of the standards to the maximum number of uses. In the article on "Standard Apparatus," appearing in this issue of the JOURNAL, Mr. Hellmund has shown how standard motors may be used to do duty on circuits having non-standard frequencies. This article is of particular interest to the consulting engineer, as it shows him how, by accepting slight compromises in performance, he may obtain practically standard motors with their accompanying advantages for service on circuits for which he would ordinarily specify special apparatus. It is hoped, however, that the article will not be the means of inducing him to adopt non-standard voltages for circuits to suit frequencies which are non-standard.

The suggestion, that standard apparatus be used to fill the requirements of special frequency circuits, is good, but its application should be limited to those cases which do not involve departure from standard voltages. It would seem to be far better to accept poorer performance of motors in some cases, and use special motors where this cannot be done, than to introduce a non-standard voltage. It, therefore, appears that the author's recommendations on this point are of questionable advisability. The electrical industry is at present handicapped by requests for special apparatus, arising largely from the great multiplicity of frequencies, voltages and phases of supply circuits, and it seems that the effort is misdirected when an attempt is made to alleviate this condition by introducing other new and special features.

While a special voltage may at first seem harmless, since adopted solely for the purpose of using standard apparatus, it is surely only a question of time when special apparatus will be required to suit the special voltage, and thus the original purpose will be defeated.

Within the past few years, great strides have been made in the right direction in the electrical industry by the adoption of standards. Now that we have them, it is the part of wisdom to make every effort to preserve them intact.

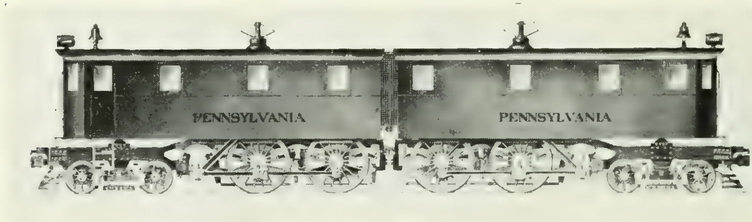
R. S. FEICHT

THE PENNSYLVANIA ELECTRIC LOCOMOTIVES

AND THEIR FIELD OF OPERATION

H. L. KIRKER

WHILE in conversation with a visiting French railway engineer the gentleman asked me to tell him something about the "Pennsylvania" locomotive. I accordingly directed his attention to the picture hanging on the engineering office wall and asked him if he recognized the similarity of the "Pennsylvania" to two "American" locomotives—without tenders, of course—coupled back to back. He said he did. He was fairly familiar with American steam road practice, so he knew the difference between an "American" and a "Mogul" locomotive, likewise the characteristics of the "Consolidation," the "Pacific" and our other types of locomotives, consequently we had a common basis for a comparison of the electric engine with



PRELIMINARY SKETCH OF PENNSYLVANIA LOCOMOTIVE
Showing new type of running gear.

the steam locomotive. His interest in the Pennsylvania locomotives was more than curiosity since his road was actively engaged in electrification. He wanted information. Hence his visit.

The "Pennsylvania," I proceeded to say, is a final type of electric locomotive in the same way that the "American" is a final type of steam locomotive. Both represent a survival of the fittest in railway evolution. Four types of electric locomotives have been tried out in arriving at the present design of a powerful passenger engine. The Pennsylvania Company has coöperated with the Westinghouse Company in the development of this machine. The design of the articulation between the two half units of this locomotive is such that the leading half serves as a leading truck and the other half as a trailing truck for travel in either

direction and, as you see, there are pony trucks at each end, consequently the Pennsylvania can work at high speed in either direction. The ability to travel at full speed in either direction means, of course, that "turning" has been eliminated as effectively as numerous other steam locomotive characteristics, such as "washing down," "coaling," "watering," etc.

Here is a diagram of the distribution of the axle loads. You observe the similarity in type to the American. You will notice also the familiar side rods connecting the drivers, and the connecting rods which couple them to the cranks on the jack-shaft, which cranks in turn are side-connected to the motor cranks. There are no gear wheels. You will note further that the jack-shaft is in the same plane as the driving axles. Now look at the motor. It is solidly mounted on the locomotive frame, which mounting makes it spring supported, of course, so far as the driving axles are concerned. This elevated position of the motor means, moreover, that the designers have been able to secure the

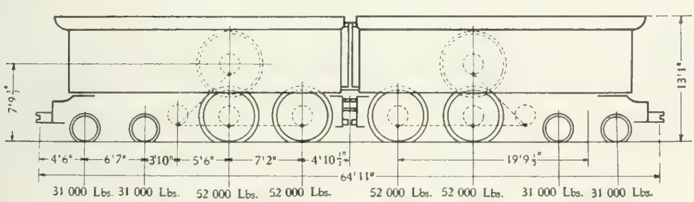


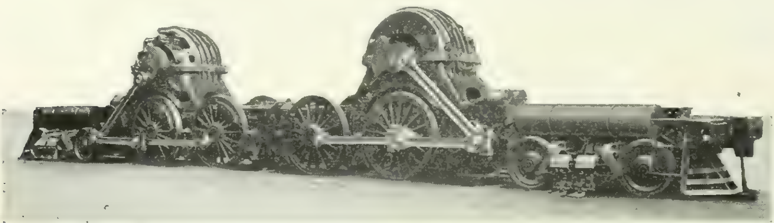
DIAGRAM SHOWING DISTRIBUTION OF AXLE LOADS

high center of gravity used in steam locomotive practice. The wheels and axles have the same freedom of motion as in the steam locomotive. However, this locomotive's catalogue of steam locomotive characteristics does not include track hammering due to unbalanced reciprocating parts. The connecting rods are rotating links which couple rotating elements, consequently are counterbalanced for all speeds. Motor drive also means uniform drawbar pull, since the turning effort of the motor is constant.

Monsieur l' Ingenieur being primarily a motive power man quickly grasped the points of similarity to which I called his attention and admitted that the electric locomotive was not such a mysterious innovation after all. He did not stop at generalities, however, but proceeded immediately to details. His questions became so numerous that by the way of blanket answer I handed him a copy of the locomotive specifications. He thanked me,

glanced at the closely printed pages, raised his shoulders slightly—would be glad to add the document, he said, to his dossier of locomotive literature, but would like if possible to see the actual machine in construction. Assent secured, we started for the locomotive aisle. En route, I ascertained that he knew the Railway Company was making the mechanical parts at their Juniata shops, was sending them to East Pittsburg for equipment and preliminary test, and subsequently was giving the completed locomotive endurance runs on the Railway Company's Long Island tracks.

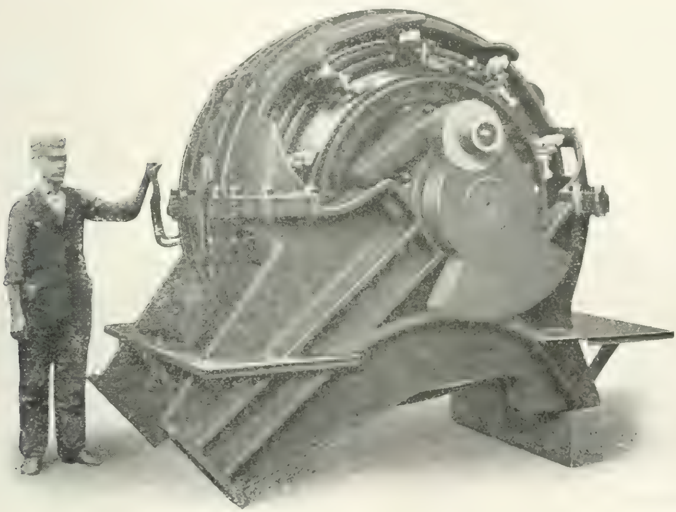
As we passed down the locomotive aisle we made a brief halt at the New Haven freight locomotives, then proceeded to the line of Pennsylvanias in various stages of completion. The first thing we saw was the running gear of the locomotive with its two motors in place. Looks like a cruiser, I suggested, as



GENERAL VIEW OF RUNNING GEAR
Showing motors mounted in position.

his eyes ran over the machine. He nodded assent. The running gear and the motors, I continued, are about all there is to the locomotive. The few auxiliaries that are required are in the cabs which you see standing on the other side of the aisle. Drop a cab over each motor, make a few connections, and you have a completed locomotive. Yes, the two half units that constitute the locomotive are identical and are permanently coupled together. The motors are connected for series-parallel operation, but either motor can, without the aid of the other, run the engine should the occasion arise. With one motor alone the locomotive can exert a tractive effort of 30 000 pounds. The maximum capacity of the locomotive with two motors is 4 000 horse-power for short periods. The normal speed is 60 miles per hour, but the engine can operate at much higher speeds than this with safety. It has the capacity required for suburban passenger service with frequent stops and is capable of accelerating heavy pas-

senger trains on the stiff grades that it will encounter in the tunnels under the river; hence the size of the machine. Its total weight is 157 tons, of which 100 tons is on the drivers. Its length inside the knuckles is 64 feet, 11 inches; its total wheel base is 55 feet, 1 inches; the total wheel base of each half unit is 23 feet, one inch and the rigid wheel base of each half unit measures but seven feet, two inches. This short, rigid wheel base, combined with the special articulation between the two half units and with the pony trucks and the high center of gravity enables this locomotive to take curves at high speeds, traveling in either direction. The driving



DETAIL VIEW OF MOTOR
Showing brush rigging, frame bracing and counterbalanced crank.

wheels are 72 inches in diameter, the pony truck wheels 36 inches.

Monsieur seemed interested in the mechanical data, so I resumed. The bumper and the articulation girders are so proportioned as to keep the stresses in the frames below 12 000 pounds per square inch, for a bump equivalent to one-half million pounds static load, 150 000 pounds of this bump being delivered along the center line of the draft cylinder and 350 000 pounds along the center line of the platform bumper. The bumper end of each half of the running gear is fitted with standard M. C. B. coupler, standard Pennsylvania platform bumper, and Westinghouse friction draft gear.

I next directed his attention to the motors and, in response to his inquiry, told him that there were but two driving motors per locomotive, one for each half unit. He admitted that he was an amateur so far as electric traction was concerned, and, after his glance had oscillated several times between the motors and the running gear, he confessed that he could not reconcile the small bulk of the motors with the bulk of the running gear. So, by the way of leading him from the known to the new, I resorted to one of the classical hydraulic analogies, the performance of the fire engine, or rather, the remarks of a certain individual on seeing for the first time a fire engine in operation—his surprise that such a diminutive piece of apparatus could contain so much water. My friend, being French, accepted the explanation and admitted that the boiler, firebox and tender were rather big items in the locomotive make-up. He fully realized, he said, the limitations of a steam plant that could be carried around on locomotive wheels, and he knew, also, something of the possibilities of a central station such as would be used to supply energy to electric locomotives. He knew that the area of the heating surface of the locomotive boiler determined the capacity of the locomotive and that but about five percent of the energy of the coal delivered to the tender was ultimately available for moving the train. I told him that the radiating capacity of the electric motor was its limiting feature, that more than 90 percent of the energy delivered to the motor was transmitted to its driving cranks and that the eight or ten percent used up as heat in the motor was all that the motor had to radiate, hence the small bulk of the motor. I pointed out that ventilation had been so incorporated in the design of this motor that the customary forced ventilation was not required. I cited the test on the locomotive that gave a drawbar pull of 79 200 pounds, the slipping point of the drivers, and reminded my motive power friend that as the weight on the drivers was 200 000 pounds total, or 50 000 pounds per axle, consequently the running gear was carrying all the driving equipment that it could utilize.

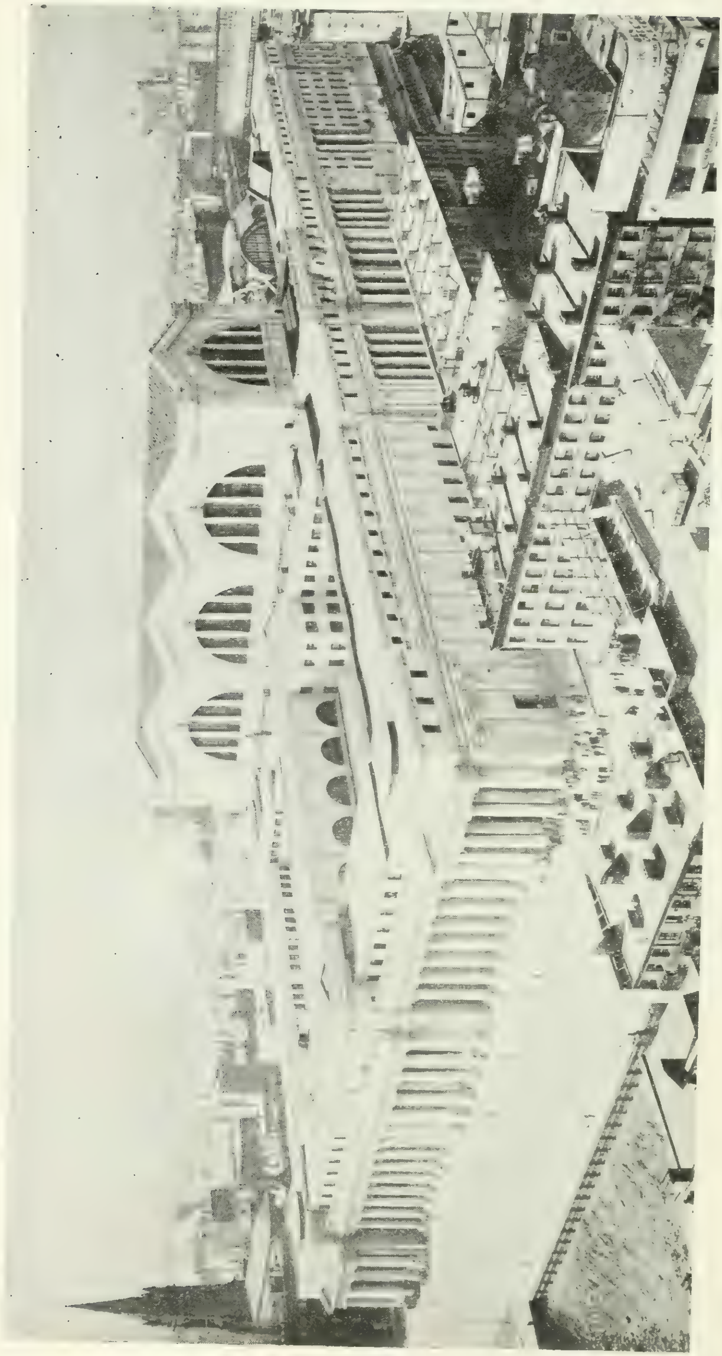
This locomotive, I continued, is distinctly a high speed passenger engine. It can exert the tractive effort of a freight locomotive when it is required to start a 550 ton passenger train up a two percent grade, as it will have to do in regular practice. The motors are, of course, series wound, and are designed for 600 volts direct current. They will take their power from a pro-

tected third rail. They are provided with commutating poles, consequently have sparkless commutation even when carrying the momentary heavy currents used in acceleration, which are far in excess of the normal running current of the motors. The ordinary speed regulation of the series motor is extended in the present instance by shunting a portion of the main field, a speed of 75 miles per hour being thus easily obtainable. Notwithstanding the good commutation resulting from the presence of auxiliary poles, provision is made to relieve the driving gear from dangerous shocks that would result in event of an accidental flash-over at the brushes. A flash-over practically stops the motor armature for an instant, and unless the shaft can slip in the armature core, the effect on the driving gear would be the same as would result from a sudden stopping of a steam engine fly-wheel, the rods would buckle and the pins would snap. The

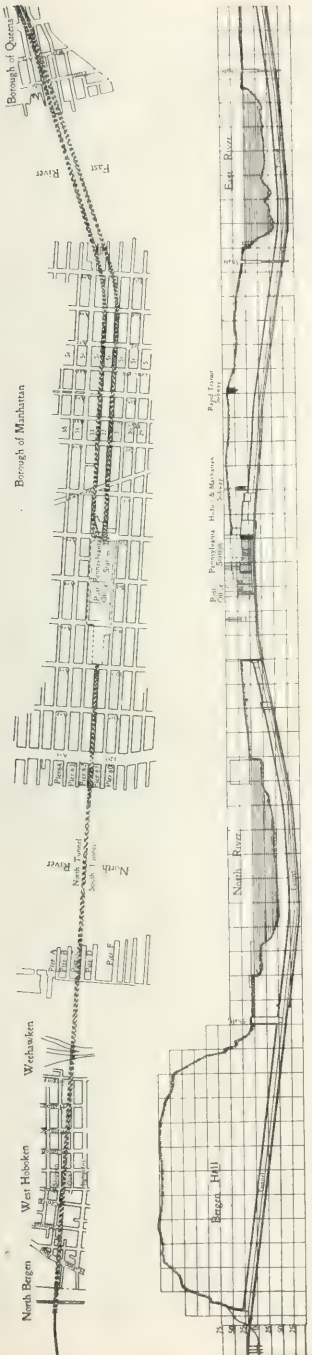
PENNSYLVANIA LOCOMOTIVE HAULING TRAIN OF STEEL PASSENGER COACHES AND PULLMANS

provision here consists of a slip clutch between the armature and its crank shaft. This clutch is set high enough to allow the locomotive to do its normal work, but it will slip at a pressure below that which is dangerous to the pins and connecting rods.

Having examined the running gear and its motor we proceeded to the cabs to inspect the auxiliaries. You see, I said, that the cabs for the two half units are identical. The bulkhead separates the driving engineer's compartment from the rest of the cab. The driver's compartment contains the controller (the throttle) and the brake-valve. It also contains the buttons that control the sanders, the bell, the headlight, the pantagraph on the roof, which collects the current from an overhead wire where gaps occur in the third rail. The starting rheostat and its switches are in the other compartment, also the air compressor. The two cabs are vestibule connected. Either end of the locomotive is the front end, the designation shifting with the driving engineer. He can run his engine forward or back from either compartment and handle a "double-



PENNSYLVANIA RAILROAD TERMINAL STATION, NEW YORK CITY
"The 33rd Street Passenger Station."



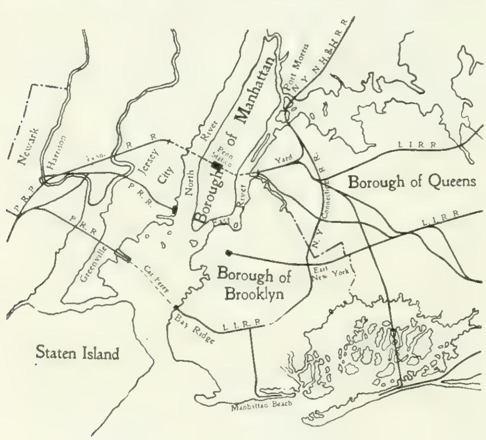
PLAN AND PROFILE MAP, PENNSYLVANIA TUNNEL AND TERMINAL RAILROAD
From Bergen Hill Tunnel to Borough of Queens.

header" as easily as a single locomotive.

My foreign friend next wanted to see a locomotive in operation. No tests were going on at the time so I had to refer him to the future scene of the locomotive's activities. He said that he had but a vague idea of the scope of the electrification work that the Pennsylvania Company was carrying out at and around New York City. He had had a "look at the map." He knew something of the magnitude of the Pennsylvania system, that it embraced more than 12 000 miles of first track, more than 6 000 steam locomotives and more than a quarter of a million freight cars. He knew that the annual freight haulage exceeded 29 000 million ton-miles, that the annual passenger business exceeded 3 500 million passengers one mile, and that the company's earnings per mile of track exceeded $35 000 per year. He knew also that the company had tunneled under the Hudson river and that it was building a magnificent passenger station in New York City, and that all told the extensions and improvements which it was making in and around New York City would amount to an investment of $150 000 000. He recognized, he said, that electric traction made this terminal transformation possible and he recognized also the significance

of such a big step by such a big railway company. He was anxious, therefore, to acquaint himself with the general scope as well as some of the details of the work. Accordingly, after a brief excursion into several adjacent sections of the East Pittsburg works, we returned to the engineering office where I showed him a key map of the situation.

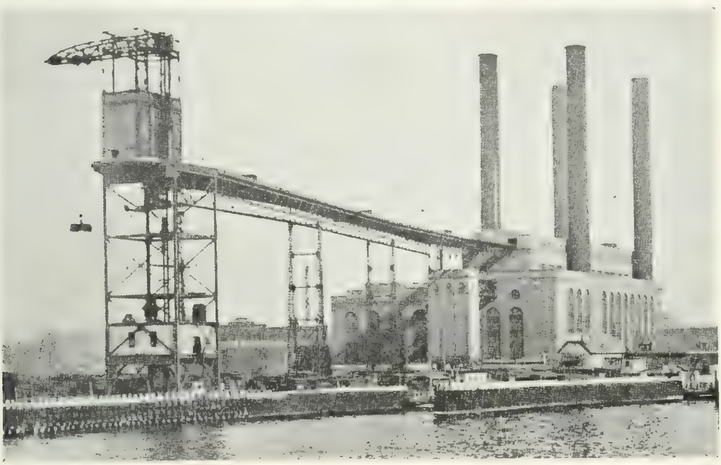
You will note, I said, that a new main line has been run from Newark, N. J., through Harrison, and across the Meadows, through the Bergen hills, under the North river, then underground to the new passenger station at 33rd street, New York City, then on underground to the East river, then under the river to Long Island City, where the tracks come to the surface and connect with the company's Long Island Railroad tracks, and will connect with the New York connecting railroad when the latter is built. You will note, also, that the Long Island Railroad extends to the eastern end of the Island, a distance of about 100 miles, and that it runs down to the Bay Ridge Terminal freight yards in the southwest corner of the Island. The corresponding terminal on the New Jersey shore is Greenville. A freight car ferry connects these two points. The New York Connecting Railroad will eventually join the Long Island tracks with the tracks of the New York, New Haven & Hartford Railroad by a north and south line on Long Island and bridges across East River by the way of the islands to Port Morris. The present main line from Newark to Jersey City will eventually be electrified. The interchange yards are at Harrison, 9.4 miles from the New York City Terminal Station. An extensive terminal station is being built at Harrison. Likewise a terminal station at Long Island City. The locomotives will be housed at



OUTLINE SKETCH OF NEW YORK CITY AND VICINITY

Long Island City, where the shops are located. The power station also is located in Long Island City, on the water front. Its present capacity is about 40 000 kilowatts, and is capable of extension to 75 000 kilowatts.

Yes—in reply to his question—the company has a legal right to run freight trains through the tunnels, but the tunnels, nevertheless, are intended primarily for passenger service. Through freight to and from New England will take the Greenville-Bay Ridge car ferry route. You will be interested in noting that this new freight route will have a ferry distance of three miles—the present route between New England and New Jersey, around

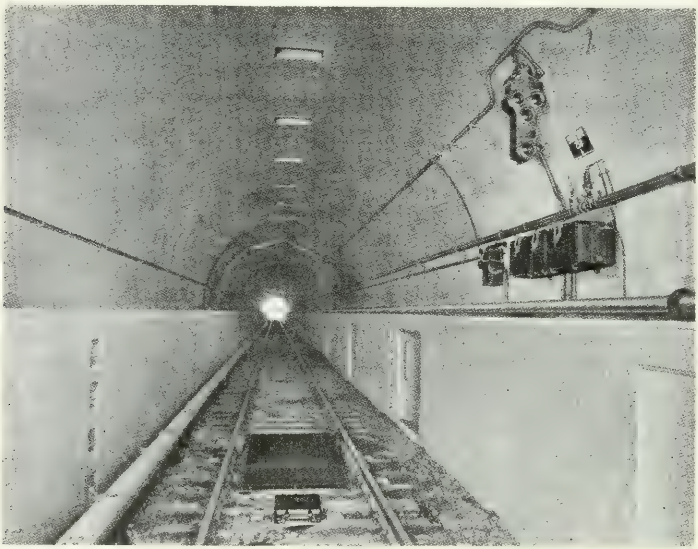


POWER STATION, PENNSYLVANIA ELECTRIFICATION
Located at Long Island City, N. Y.

New York City, includes 12 miles travel by water. The elimination of the car ferries from the North river will mean a distinct improvement in navigation facilities, so will the disappearance of the company's passenger ferries which have been carrying about 90 000 passengers per day between Jersey City and New York.

New York City owes its position as a metropolis mainly to its facilities as a port. Its harbor is one of the finest in the world, so it is not surprising that the city's foreign commerce is more than half of the country's total. The fact, however, that the city proper is on Manhattan Island has, till now, kept the Pennsylvania Company's tracks a mile short of the country's greatest

city. Financiers and engineers have proposed bridges and tunnels for closing the gap, but the bridge projects have never secured the necessary financing nor have satisfactory means been found for making a tunnel tolerable for steam locomotive service. The solution of the tunnel problem came with the electric locomotive. Tunnels now bridge the gap. Through trains from the South and West will now run into the heart of New York City and thence on into New England by the way of the Long Island



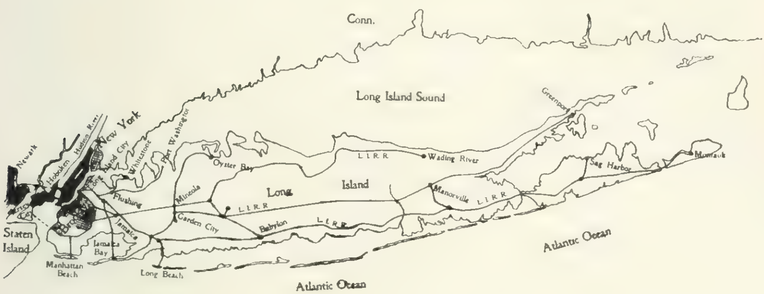
INTERIOR OF PENNSYLVANIA TUNNEL
Showing signal apparatus.

tracks and the Hell Gate bridges. The electric zone will reach from Harrison, N. J., to Jamaica, Long Island, a distance of 20 miles. The electric locomotives will shuttle between these points through the new passenger station at 33rd street, some of them hauling through passenger trains and the others hauling suburban traffic. Twenty-four locomotives will perform the heavy work in the electrified zone.

In addition to the electric locomotives, 280 multiple-unit passenger cars are being supplied. These cars will operate in trains of various sizes up to nine cars. Some of these multiple-unit trains will operate between the same points as the electric locomotives, the others, however, on the general network of the

electrified tracks. There will be no steam locomotive operation in the electrified zone. The initial electric service will be 500 trains per day in and out of the New York City Station. The ultimate capacity of this station is 1 000 trains per day.

The subject of railway strategy greatly interested the French engineer, who, with the vivid imagination characteristic of his race, saw great possibilities for the electric locomotive. He knew of some of its feats in terminals and tunnels and on mountain grades. He realized what a relief it would be to roads distant from coal mines but within the reach of water power. He



OUTLINE SKETCH OF LONG ISLAND, NEW YORK CITY AND VICINITY

anticipated the time when the railroad companies could buy electric power as they now buy coal. Finally, as he bade me farewell, he said that on the occasion of his next visit he hoped to land at a port on the eastern end of Long Island and ride behind a Pennsylvania electric locomotive into New York City. I supplemented this with the suggestion that if he delayed his visit several years he was just as apt to find at the same port Pullmans for the Pacific Coast, and in case he took the trip across the continent, electric locomotives would haul his train through many tunnels and city terminals and over numerous mountain grades.

STANDARD APPARATUS

ITS USE ON STANDARD AND SPECIAL FREQUENCIES

RUDOLFH E. HELLMUND

IT is proposed herein to offer a few suggestions which may be effective in bringing about the use of standard apparatus in connection with special frequencies wherever the conditions will allow the adoption of an operating voltage which is favorable to the accomplishment of this result. The desirability of extending the use of standard electrical apparatus as far as possible to the exclusion of special designs is generally recognized, since the advantages accruing from standard apparatus are equally important to the manufacturer and the consumer. The most important advantages for the consumer are that he may buy standard apparatus for less money and that he will at the same time obtain better and more reliable equipment, it being evident that special apparatus, which is possibly being built for the first time, cannot always have the same degree of excellence as standard apparatus, which has been carefully developed and which, in most cases, represents improvements based upon experience gained in practice in connection with previous applications of the same type.

It is a matter of course also that the deliveries on special apparatus cannot be compared with those for standard apparatus, a very serious disadvantage to a consumer whose needs may be urgent. Then, too, a direct loss almost always results in case of breakdown of apparatus if repair parts cannot be obtained promptly, as is often the case with special apparatus. There are, of course, numerous cases where the use of a special apparatus, as, for instance, an electric motor designed for special speed characteristics, has certain advantages, so that its use in place of a standard machine is fully justified.

Again in other cases the use of special apparatus is necessitated on account of existing conditions, which could be changed only by spending much money. This may be the case where the available power is of a special nature, as, for instance, when an alternating-current system of special frequency is supplying the power. This latter case will bear of consideration somewhat in detail.

FACTORS TO BE CONSIDERED

In studying the possibilities of using standard apparatus in connection with alternating-current industrial and other power

plants, the generators, the transformers, the motors and their starting devices all have to be considered. As a rule the motors are the most important factor since they represent the largest part of the invested capital. Since they require more frequent repair, the availability of standard repair parts is, therefore, of greater importance than for transformers. The use of standard generators is not quite as important as the use of standard motors, since in any event the generators are not ordinarily kept in stock by the manufacturers and, therefore, some of the drawbacks of special apparatus are eliminated in this case. Moreover, in all probability there will be few generating stations with special frequencies installed in the future and the demand for generators will be chiefly for extensions, where the voltage of the generators is already fixed. In contradistinction to this the motor voltage in extensions of old plants can be fixed at any convenient value by simply using the corresponding transformer ratio. The starting apparatus, as a matter of course, is not as important as the motors, since they usually represent but a small part of the investment. Moreover, within certain limits, most starting apparatus may be used over a considerable range of voltage and frequency.

In considering the choice of potential for a motor to be operated at a special frequency it should be noted primarily that the standard motors have a certain fixed size of conductor, which is capable of carrying a certain current without undue heating. The amount of this current is influenced to some extent by the ventilation and consequently by the speed of the motor; it is also slightly dependent upon the losses in the core and the heating caused thereby, although this latter influence is smaller than usually assumed. The core losses in an induction motor may be varied within rather wide limits and will influence the heating of the winding only a few degrees. Beside the heating, the motor performance should be given some consideration. It should be kept in mind that increasing the magnetic density means mainly an increase in the ratio of magnetizing current to full-load current, and since the magnetizing current represents the larger part of the wattless component of the total motor current, an increase of this ratio results, in most practical cases, in a decrease of power-factor. The efficiency also may change whenever a motor is operated under different frequency conditions, if the current density and magnetic density are not both altered to correspond. With proper adjustment of these factors, however, an efficiency may be effected that is

nearly as high as would be obtained if the motor were especially designed for the particular frequency. A material decrease of the magnetic density at which a motor is operated of course means a weaker field and will result in a reduction of the pull-out torque of the motor. The starting torque in squirrel cage motors is also affected by the magnetic density and by the frequency as well, but as a rule it can be adjusted to the desired value by merely changing the material or the dimensions of the resistance rings. With these facts in mind the special frequencies which are used, or may be used to some extent in the future, will be considered in view of their relation to present practice in motor design.

15 CYCLES

Motors—A frequency of 15 cycles per second is at the present time used very little for induction motors. The possible adoption of this frequency for railway purposes may, however, lead to quite a demand for 15 cycle industrial motors to be operated in connection with railway systems. The present standard frequency closest to 15 cycles is 25 cycles, and a strong attempt should be made to adopt such a potential for 15 cycle operation as will allow of the use of 25 cycle motors.

In employing a 25 cycle motor for 15 cycles the speed of the motor is reduced in the ratio of 15 to 25, and of course the horsepower rating of the motor, as well as the electrical input, is decreased in approximately the same proportion. On account of the reduced frequency the core losses are diminished considerably if the flux densities in the iron are not changed. It seems, therefore, advisable to increase the iron densities by quite an appreciable amount. Unfortunately, however, special conditions make this impossible. The highest synchronous motor speed possible with 15 cycles is 900 r.p.m., and by far the largest number of all motors up to 30 or 40 horse-power will be used with this speed; in other words, the two-pole 25-cycle motors are chiefly to be considered. However, in almost all commercial makes of two-pole, 25 cycle motors the iron is worked at so high a saturation that any considerable increase of the saturation would lead to very poor performances and would not be advisable even though the heating limit of the iron were not reached.

The largest advisable increase of core density would, therefore, be about ten percent. Assuming the same core density at 15 cycles as at 25 cycles, the operating voltage would be reduced in di-

rect proportion to the reduction in frequency. Thus, the voltage for a 220 volt, 25 cycle motor on a 15 cycle circuit would be 132 volts plus an increase of core density of ten percent at 15 cycles, or 145 volts. The corresponding potentials for 25 cycle motors would accordingly be, approximately:—

For 220 volt, 25 cycle motors, 145 volts on a 15 cycle circuit.
For 440 volt, 25 cycle motors, 290 volts on a 15 cycle circuit.
For 550 volt, 25 cycle motors, 360 volts on a 15 cycle circuit.

If, moreover, the rating is reduced in proportion to the speed of the motor, the motor currents will be, with the 15 cycle conditions, about seven to ten percent lower than with the standard 25 cycle rating. This means that the copper losses are reduced by 13 to 19 percent, which is about sufficient to counterbalance the decrease of ventilation caused by the speed reduction of the motor. The above potentials should, therefore, prove to be practical for operation on a frequency of 15 cycles. Slightly higher potentials may be somewhat more advantageous in cases where only large motors are being used and where the use of two-pole machines is limited.

In the case of a standard 550-volt, 25 cycle, star-connected, three-phase motor in which an increase of about 15 percent in the motor core density is not too high, it is even possible to operate it on a 15 cycle circuit at a standard voltage of 220 volts by rearranging the windings in delta connection, this potential corresponding to an increase of 15 percent above the normal 15 cycle voltage and accordingly to an increase in the core density of 15 percent.

Effect on Motor Performance—The above statement may be further demonstrated by the following:—Curve *A*, Fig. 1, shows the power-factors at various loads of a 75 hp six-pole, 25 cycle, 550 volt, star-connected motor. Curve *B* shows the power-factors of the same motor reconnected in delta and operated on a 220 volt, 15 cycle circuit, in which case the motor is good for 45 hp. Although the full load power-factor for the latter condition is somewhat lower than that for the 25 cycle case, it is sufficiently high, since a certain reduction in power-factor is quite justified for a 45 hp rating. The curves show also that the maximum horse-power output has in each case about the same value as compared with the full load rating. Curves *A′* and *B′*, Fig. 1, show the comparison of the efficiencies for the same conditions. The full-load efficiency for 15 cycles is somewhat too low. This, however, could easily be changed by using secondary end rings of somewhat lower resistance, thereby reducing the losses and raising the efficiency in proportion. This is quite permissible, since the starting torque for the 15 cycle condi-

tions is relatively higher than for the 25-cycle rating. It follows that a 15 percent increase in density is quite advisable in this case.

The same comparisons for a five hp, two-pole, 25 cycle, 550 volt, star-connected motor are given in Fig. 2. Curves *A* and *A′* give the 25 cycle case, and curves *B* and *B′* show the operation of the motor reconnected in delta and operated on 15 cycles and 220 volts. As previously noted, the motor performance for this and similar cases is rather poor under these conditions. The curves *C* and *C′* of Fig. 2 show the same motor star-connected and oper-

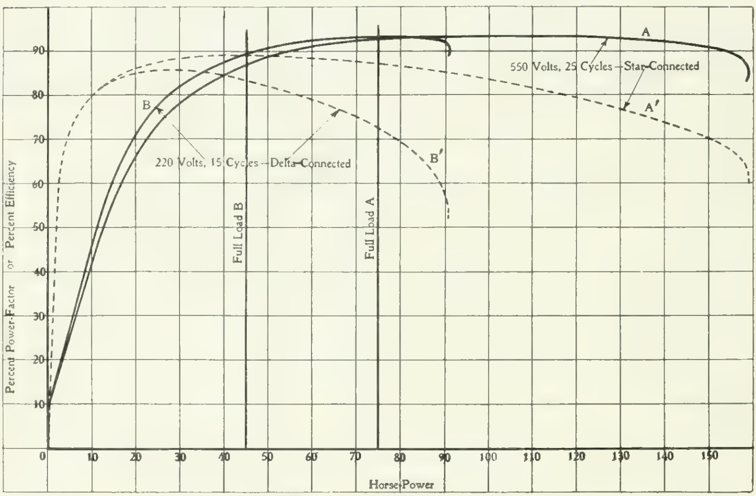


FIG. 1—POWER-FACTOR AND EFFICIENCY CURVES

Showing effect on output and performance of a 75 hp, six-pole, 550 volt, 25 cycle, induction motor, of operation on a 220 volt, 15 cycle circuit. *A* and *B*—Power-factors. *A′* and *B′*—Efficiencies.

ating on a 15 cycle, 360 volt circuit, corresponding to a ten percent increase in density. Under these conditions the motor performance is quite fair for a three hp motor and could be further improved by changing the resistance rings.

Starting Devices—After having determined the proper voltages for the motors the effect of reduction of voltage and frequency on the operation of the starting devices remains to be considered. The auto-starter is the most important. The switches are, of course, sufficient for the altered conditions, since current as well as potential has been decreased. The auto-transformer, however, is affected similarly to the motor and with changed voltage and frequency will be about right for the reduced output, except possibly in cases where a motor is reconnected from star to delta. This is often

impossible with auto-transformers, since they are usually V-connected. Although it might be possible to accomplish some saving in material by special design of transformers, in most cases this would be hardly worth while and a standard auto-starter designed for the 25 cycle motor rating could be used to good advantage without modifications for the 15 cycle conditions.

In some cases involving wound secondary motors a slight change in the resistance units may be found advisable, since with a 25 cycle motor operating, as outlined above, on a 15 cycle cir-

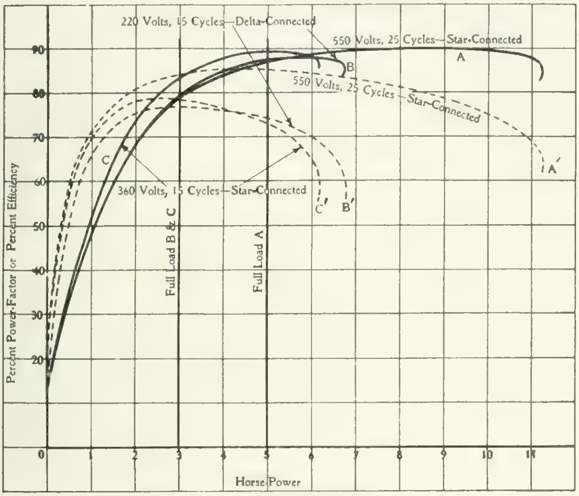


FIG. 2—POWER-FACTOR AND EFFICIENCY CURVES

Showing effect on output and performance of a 5-hp, two-pole, 550 volt, 25 cycle induction motor, of operation on a 220 volt, 15 cycle circuit and on a 360 volt, 15 cycle circuit. *A*, *B* and *C*—Power-factors. *A′*, *B′* and *C′*—Efficiencies.

cuit and at a correspondingly reduced voltage, the secondary voltage is also lower than when operating on 25 cycles, since the ratio between primary and secondary voltage is a constant value fixed by the motor design. In making such a change, the size of the secondary resistance required may, of course, be determined on the basis of the energy to be consumed in the starting rheostat, which corresponds approximately to the energy which would be represented by the output of the motor if delivering the desired torque at full speed. The energy transmitted through the rotor is practically constant with a given torque regardless of the speed; hence at starting, the energy which appears as mechanical power when the

motor is running has to be dissipated in the external resistance as electrical energy. Otherwise, the secondary remains practically unaffected by the change in frequency. Therefore, the contact devices, as for instance the drum controllers, designed for the 25 cycle rating may be used without change.

Transformers—The possibility of using standard transformers in the 15 cycle system, depends of course upon the high-tension voltage as well as upon the motor potential. If, however, the high-tension voltage be chosen so as to have the same ratio to the standard 25 cycle high-tension voltage as that of the proposed 15 cycle motor voltage to the 25 cycle motor voltage, it would of course be possible to use the standard 25 cycle transformers with a correspondingly reduced rating. It would also be possible here, as with the auto-transformers, to obtain a slightly better economy by special design for 15 cycles; nevertheless, it would doubtless be found more convenient to be able to use 25 cycle transformers in cases where the number of transformers required is not large enough to justify a special design.

Generators—The generators for 15 cycles need hardly be considered in this connection. The use of a frequency of 15 cycles will probably be in connection with railroad work, where the generator units are very large, and in these cases any sacrifices in economy or design for the purpose of taking advantage of the possibility of using standard 25 cycle generators would therefore hardly be justified.

25 CYCLES

Motors—After having considered in detail the operation of 25 cycle apparatus on 15 cycles, the various other cases may be disposed of more briefly, since most of the conclusions thus far reached will be the same or similar for the other frequencies.

This frequency is considered to be standard in this country and some manufacturers carry 25 cycle motors in stock for the standard speeds for use on circuits of 220, 440 and 550 volts. The use of 550 volts is, however, not common, so that motors for 550 volt circuits are not so apt to be found in stock as those for 220 and 440 volts; therefore 550 volt plants are not much to be recommended from this point of view.

For a plant which is liable to require the use of a considerable number of motors for speeds which are lower than the usual standard 25 cycle speeds, the choice of 220 volts as the operating voltage has certain advantages over the use of 440 volts. This is

because it is possible to obtain low speeds and fairly good results by using standard 60 cycle, 440, or in some cases 550, volt motors of the proper number of poles on 220 volt, 25 cycle circuits. However, some precaution is advisable with such applications in the matter of fixing the ratings. If a 440 volt, 60 cycle motor is fairly liberal in design it may be possible to obtain about one-half of the horse-power rating on 25 cycles. In the majority of cases, however, there is danger of overheating, since the copper losses are unchanged, while the ventilation is considerably reduced on account of the materially lower speed. This is counterbalanced in only a small degree by the reduction of the core losses. Consequently, the horse-power rating at 25 cycles may have to be limited to less than one-half. If a 440 volt, 60 cycle motor were operated on a 220 volt circuit having a frequency of 30 cycles, the magnetizing current would remain unchanged, and, accordingly, the power-factor would be the same as that for normal operation on 60 cycles. The effect, then, of operation at a frequency of 25 cycles with a reduction in voltage of only 50 percent is to increase the magnetizing current, and, therefore, to decrease the power-factor. The power-factor, moreover, is further decreased if the horse-power rating also has to be reduced to less than one-half, as the ratio of magnetizing current to load current is therefore further increased. Hence, the use of a 60 cycle motor on a 25 cycle circuit with a reduction of voltage from 440 volts to the next lower standard potential of 220 volts may in some cases be found to involve relatively low power-factors and efficiencies at a 25 cycle rating. Not only is the decrease in power-factor and efficiency justified due to the reduction in horse-power, but the decrease in efficiency is also to be expected because of the lower frequency, as a 25 cycle design inherently involves a lower efficiency, unless a more expensive design is used. In such cases, where good power-factors are essential it may be found advisable to use a 550 volt, 60 cycle motor for 25 cycles and reduce the rating as far as the considerations of heating may require, i. e., to between 35 and 45 percent of the 60 cycle rating.

Generators, transformers, etc., are standard for 25 cycles and do not need to be considered here.

30 CYCLES

Motors—There is a limited number of plants operating on a frequency of 30 cycles; also a few having a frequency of 33 cycles. Most of these plants are operated with voltages of 220 or 440 volts on the motors or even 200 or 400 volts. While it is possible to

operate most standard 25 cycle motors satisfactorily under these conditions with their 25 cycle horse-power ratings, it is not possible to use the motors to their best advantage. Since the speed of the motors increase in the ratio of 30 to 25 when they are operated on 30 cycles instead of 25, they should be capable of giving a corresponding increase of horse-power output. This result could easily be obtained if a motor potential of about 250 or 500 volts, as the case might be, were selected as the operating voltage. In this case the iron density would be slightly lower than when the motors were operated with their normal frequency; however, since the frequency is increased, the core losses would be but slightly changed. If the motor rating were increased in proportion to the frequency the motor current would be slightly larger than under the 25 cycle condition. The higher speed would, however, give improved ventilation and accordingly excessive heating due to the increased copper losses would be obviated.

Generators—Similar considerations apply to the standard 25 cycle alternators; the large majority of these will operate very satisfactorily at a frequency of 30 cycles with a 14 or 15 percent increase of potential.

Transformers—In the case of transformers it would hardly be possible to increase the rating in proportion to the frequency since in this case the somewhat increased losses are not compensated for by increased ventilation. They will, however, operate satisfactorily with a rating of about ten percent above their 25 cycle rating. The same applies to the auto-transformers. The other starting devices, with few exceptions, will operate satisfactorily under the changed conditions, since their capacity is practically dependent upon the current, which is only slightly increased.

As in the case of 25 cycles it is possible to use standard 440 volt, 60 cycle apparatus to some extent on 30 cycles if the operating potential is 250 volts.

40 CYCLES

Similarly it may be shown, that 220 and 440 volt, 25 cycle motors may be operated on 40 cycle circuits at 330 and 660 volts, respectively, as the operating potentials. On the other hand, it is possible to use 220 volt and 440 volt, 60 cycle motors to good advantage on 40 cycle circuits with 165 and 330 volts respectively. In both cases the rating must, of course, be changed to correspond with the change in frequency.

It is, therefore, at once obvious that 330 volts is a potential

which is to be recommended for 40 cycles, since with this potential it would be possible to use standard 25 cycle as well as 60 cycle motors. A potential of 330 volts is also to be preferred to 660 volts, since the latter voltage is somewhat too high for the standard insulation of low voltage motors. A potential of 165 volts is lower than desirable, since it necessitates very heavy conductors for motors of the larger capacities.

Standard 25 cycle motors for 220, 440 and 550 volts with moderate densities and designed for star-connection, may also frequently be operated satisfactorily on 40 cycle circuits with an operating potential of 200, 400 or 500 volts, respectively, if they are connected in delta. A potential of 200 volts will also give fairly good results on 440 volt, 60 cycle motors under the same conditions. In the latter case, however, the motors are worked as much as 18 percent above their normal core densities; accordingly, a high magnetizing current and consequently somewhat low power-factors will result. This will be especially true if the initial densities at the standard frequency are already rather high. In spite of this, in many cases this voltage may be more advantageous than 330 volts, because it is sometimes desirable to use lamps on 40 cycle motor circuits and it is possible to use standard makes of lamps for 200 volts.

50 CYCLES

For motors on 50 cycle circuits it is quite customary to use standard 60 cycle motors of equal rating and potential. This is, however, only possible if the 60 cycle motor is rated quite liberally. If, on the other hand, it is rated closely, it will not operate on a 50 cycle circuit of equal potential without dangerous heating, this being due to the fact that the motor speed and, therefore, the ventilation, is reduced, while the losses are not decreased. In any case, a 60 cycle motor operating on a 50 cycle circuit of equal potential will always have a poor power-factor, especially if the 60 cycle motor is designed for high core densities. It, therefore, seems more advisable to operate 50 cycle circuits with potentials somewhat lower than the standard 60 cycle potentials and also to reduce the ratings of the motors ten to twenty percent. As a rule, it is possible to obtain good results with 220, 440 or 550 volt, 60 cycle motors by using 200, 400 or 500 volts, respectively, as the operating potentials.

60 CYCLES

The frequency which is used most frequently in this country is 60 cycles, and apparatus of all kinds is standardized for this frequency and for operating potentials of 220, 440 and 550 volts. Of

these three voltages the 440 volt standard is somewhat to be preferred to the others, since with this voltage it is possible in some cases to utilize 220 volt, 25 cycle motors. This is quite convenient in meeting requirements for high speed motors which are not used frequently enough to justify carrying them in stock. For such high speed applications standard two, four or six-pole, 220 volt, 25 cycle motors can be used on the 440 volt, 60 cycle circuits.

FREQUENCIES ABOVE 60 CYCLES

It is possible to find a few cases where frequencies such as 66 or 72 are employed and it is, of course, customary to use 60 cycle apparatus. In these cases again good results are obtained by increasing the potentials somewhat less than in proportion to the frequency. Thus 235, 470 and 590 volts would be best for 66 cycle operation, and 250, 500 and 625 volts best for 72 cycles.

ADVANTAGES OF STANDARDIZATION OF VOLTAGES

It is obvious from the foregoing that, with proper choice of voltage, a large percent of all apparatus used in connection with special frequencies may be of standard make and that in this manner the amount of special apparatus may be largely reduced. In fact, it seems advisable always to give preference to the voltages indicated by the curve of Fig. 3 for special as well as standard frequencies. This would lead to great flexibility in the application of all kinds of alternating-current apparatus; especially of induction motors. The curve represents the conclusions arrived at in the above considerations. It might appear that the proposed curve is rather of academic than practical value, on the ground that, as previously mentioned, new plants with special frequency will hardly be installed in future, and the potentials for existing plants are already fixed. This, of course, makes the general adoption of an ideal potential curve such as has been suggested impossible. Nevertheless there doubtless are cases and will be numerous future cases, where its application and a consideration of the other suggestions given herein will prove advantageous.

For 15 cycle applications, for example, the adoption of an advantageous voltage for the motor circuits should be given careful consideration. The use of either 145 or 290 volts seems in this case especially feasible, since standard lamps need hardly be considered in connection with 15 cycle circuits, and, therefore, adherence to any of the present standard voltages is of little consequence.

The use of 25 cycle motors on 60 cycle circuits and vice-versa

may be made a matter of common practice, provided the potentials are in line with the curve, Fig. 3.

Again, the writer is familiar with a number of recent extensions made in connection with 30 and 40 cycle plants where the adoption of a new voltage would have been quite feasible, since in each case the extension formed a separate and distinct unit of load on the power station and the question of interchangeability of apparatus between the old and new plant was, accordingly, of little importance. If, as in one recent instance of a 30 cycle plant, the existing voltage is 200 volts the old motors will probably be found

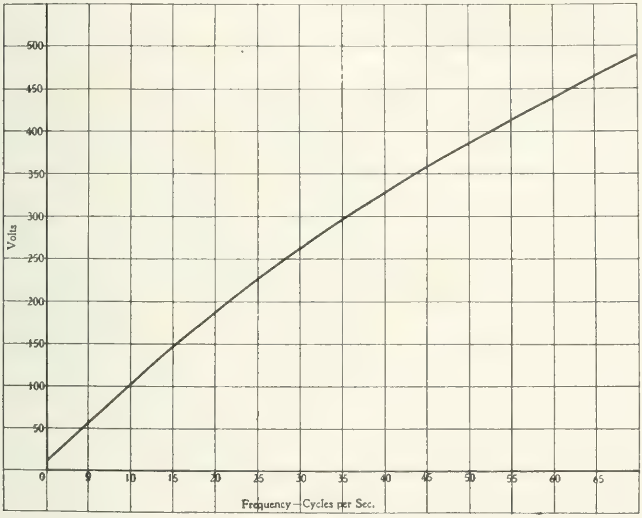


FIG. 3—PROPOSED STANDARD FREQUENCY—VOLTAGE CURVE

This curve indicates the voltage which, if employed in connection with the respective corresponding frequencies, will result in the operation of apparatus at approximately uniform core densities. By adherence to the relations between frequency and voltage indicated, the range of application of standard apparatus can be broadened and the required number of different designs minimized. Allowance is made for the use of somewhat reduced densities at the higher frequencies, as indicated by the drooping character of the curve.

to be standard 220 volt, 25 cycle motors, and the question of interchangeability may be considered. The motors supplied for the new voltage of 250 volts, (See Fig. 3) will also be 220 volt, 25 cycle motors, i. e., they will be interchangeable, and, moreover, the motors connected to the new 250 volt circuits will be good for an increased output of 25 percent at the increased speed. In other words, the motors for the new circuit will be correspondingly cheaper per

horse-power output, which advantage may be gained without interfering with the interchangeability of any of the apparatus except the transformers.

Circuits for 50 cycles are so numerous, that the chances to adopt desirable potentials for new extensions are by no means a rare occurrence. All that is necessary for obtaining the desired voltage for extensions is to install transformers giving the proper ratio of transformation.

In the majority of industrial plants the total transformer capacity installed for supplying power for motors represents but a fraction of the total motor capacity because of the low load-factors which ordinarily obtain in such plants. In view of these facts the economy of investing in transformers giving an advantageous motor voltage is obvious. In many cases, the primary voltage or frequency available for supplying power to extensions of present systems of special frequency would be such as to require transformer coils of special design even if an ordinary standard secondary voltage (such as 220 or 440 volts) were to be provided. Accordingly, the most suitable motor voltage indicated by the above considerations could be provided without involving additional cost or difficulties. Even in cases where a sufficient amount of apparatus of special frequency is involved to warrant a special design best adapted for the conditions at hand, it may still be found advisable to follow the above suggestions, in view of the fact that this would make the special apparatus of greater relative value, inasmuch as it could then be used on circuits of standard frequencies as well.

The possibility of using standard apparatus is not the only consideration in designing electrical equipments, and it may not always be practical to adopt the potentials which would obviously be best from this point of view. There are a number of factors which are adverse to an adherence to the proposed frequency-potential curve. For example, the low potentials proposed for low frequencies might lead to excessive investment for copper in the distribution system, which of itself might necessitate the adoption of a higher voltage. Again, special voltages would interfere with the use of standard lighting apparatus on the power circuits. It is also appreciated that the introduction of new potentials in addition to the multitude of combinations of frequencies, potentials, and phases already existing is open to criticism. Nevertheless, the question of making possible the use of standard apparatus in the lay-out of any installation is *one* of the important factors to be considered.

WINDING OF DYNAMO-ELECTRIC MACHINES — IV

SMALL INDUCTION MOTORS

BASKET AND DIAMOND TYPE

THE induction motor is one of the most rugged of all dynamo-electric machines, as it is made up of but two separate windings, one mounted in a stationary and the other in a rotating core, without commutator or other complications. The stationary winding is subject only to electrical stresses which can be readily taken care of under normal conditions. The rotating winding is subject to both electrical and mechanical stresses, but it can be made practically indestructible by correct design and proper workmanship in assembling.

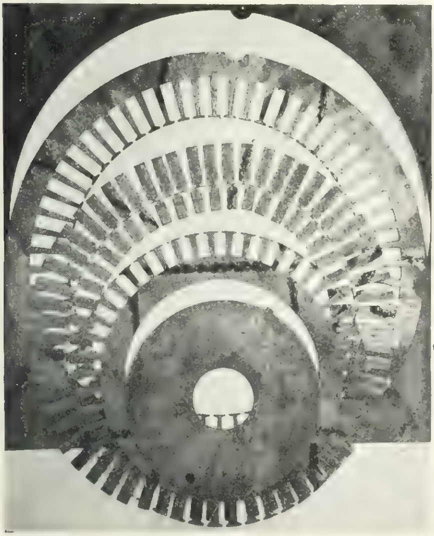


FIG. 52—PUNCHINGS FOR INDUCTION MOTOR CORES

THE STATIONARY CORE

The core for induction motor stators is made up of steel laminations of the form shown in Fig. 52. In assembling the core, the frame is placed in a special jig, having a smooth expansive center, over which the laminations are fitted. An end ring is slipped down to the bottom of the frame until it rests against a shoulder turned on the frame ribs. A steel drift for aligning the slots is inserted into a hole in the jig, and the laminations are put in place one by one, taking care that all burr sides lay one way. One or more of the frame arms has a semi-circular keyway cored into it, and the punchings are assembled with the keyways in the punchings one above the other and opposite the keyways on the frame. Ventilators are not usually inserted except on the wider cores. After the specified weight of laminations has been assembled, the jig is expanded until the punchings are exactly centered. The end ring is

then put in place, the top frame of the jig placed in position and the core is compressed until ring keys can be inserted into the keyways over the end ring, Fig. 53. Melted babbit metal or other suitable alloy is then poured into the keyway between the core and the frame. The motor frame is then removed from the jig, the edges of the slots are filed smooth and the core is ready for the windings. The slots may be open or partially closed. Ordinarily, small machines for the lower voltages have partially closed slots, while larger machines, or machines for voltages greater than 550 volts have open slots and specially insulated coils.

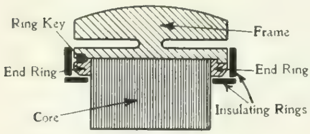


FIG. 53—SECTION OF STATOR CORE

PARTIALLY CLOSED SLOT WINDINGS

The assembly of the coils in a machine of the partially closed slot type differs from the same operation in other types in that the coils are threaded through the opening into the slot one wire at a time, and the only insulating material on the coils is the cotton covering on the individual wires. This being the case, all the insulating material which separates the coil as a whole from the other parts of the machine must be placed in the slots prior to the insertion of the coil.

Slot Insulation—Before the slots are insulated they are carefully examined for defects, and any dirt or filings are removed with an air blast. The slot insulation for either type of threaded in coils, consists of an outer cell of fish paper, which possesses the requisite mechanical strength to protect the inner layers from damage, and an inner cell of treated cloth, which has high insulating qualities but less mechanical strength. The fish paper cell is of sufficient width to completely line the slot, as shown in Fig. 54, and long enough to extend beyond the iron far enough to prevent creepage. In general, this is about three-quarters of an inch on each side of the laminations. The inner insulating cell is long enough to project beyond the protecting cell about a quarter of an inch at each end, and wide enough to extend through the top of the slot about an inch. The projecting part of this cell helps to guide the wires through the opening into the slot, and protects them from injury by coming in contact with the laminations.

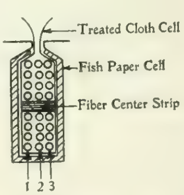


FIG. 54—SLOT INSULATION

End ring insulation, consisting of fullerboard rings and fiber strips, is placed on either side of the core, as shown in Fig. 53, to protect the overhanging ends of the coils from coming into contact with these parts.

Basket Type—One Coil Per Slot—Basket coils are wound to a shape corresponding only approximately to their final shape, as shown at the left, Fig. 55. It is important only that the total length of the loop be correctly proportioned so that the ends may be formed to the proper shape after the wires are in the slot. In the absence of a suitable mould, the coil may be wound around two pegs spaced the proper distance apart. Small pieces of tape are fastened around the coil at convenient points so that the wires may be held together while they are being threaded into the slot. Basket coils are largely used with a one coil per slot winding. This mean that each side completely fills one slot, so that a 48 slot core requires 24 coils for a set. In this class of winding one end of the coil has to drop below the bottom of the slot in order to permit the adjacent coil to pass over it, while the other side of the same coil remains on a level with or only slightly below the top bore of the slot.

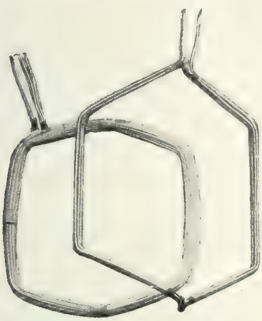


FIG. 55—STATOR COILS
Basket coil at left. Diamond coil at right.

Assume, for example, that a 48 slot core is to be wound for a four-pole, three-phase machine with a throw of *1* and *12*. Two slots are marked to serve as a guide to the winder in placing the coils with respect to their proper span or throw. Unless otherwise specified, any slot may be considered slot *1* and the other slot located by counting the throw in a clockwise direction. In this case the lower side of the first coil will go in slot *12*, Fig. 56. This side of the coil is now laid wire by wire inside the insulating cell in slot *12*. The projecting edges of this cell are then cut off close to the laminations, the ends are folded over one another and the slot is closed by driving a tight-fitting fiber wedge between the outer cell and the tips of the teeth. This retaining wedge should

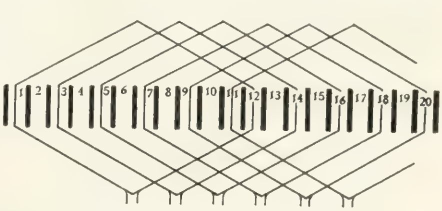


FIG. 56—WINDING DIAGRAM FOR BASKET COILS

not extend more than one-half inch beyond the core on either side, as it is liable to curl up and rub against the rotor. That part of the coil projecting beyond the slot is now taped with a layer of treated tape and a covering of cotton tape for about half its length on each side of the core, and formed to drop below the bottom of the slot. This is known as the bottom part of the coil, as distinguished from the other side which will remain on a level with the slots known as the top part. In continuing the winding, the top part is, for the present, left out of slots *1*, *3*, *5*, *7* and *9*, since in completing the winding the coils in slots *2*, *4*, *6*, *8* and *10*, which drop below the slots, must be in place before these top parts can be inserted. These coils which have one side left out of the slot until the rest of the winding is completed, are known as throw coils. In the present case they will be seen to be *1-12*, *3-14*, *5-16*, *7-18*, *9-20*. In Fig. 57 the method of winding is shown, several throw coils being seen on that portion of the core next to the winder. The throw coils are generally taped temporarily wherever they are exposed, to protect them from mechanical injury while the rest of the coils are being inserted.

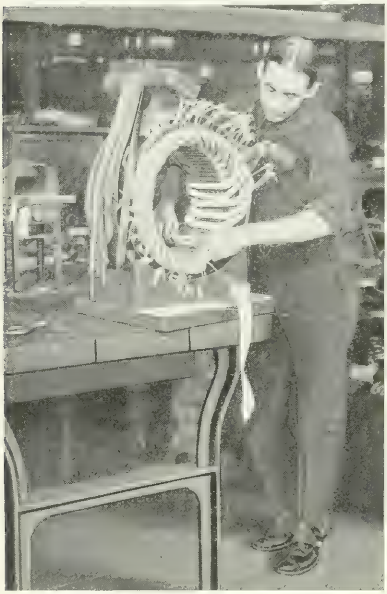


FIG. 57—INSERTING BASKET COILS

The first coil that can be wound into two slots as a top and bottom coil is *11-22*. The coil in slot *22*, being a bottom coil, is inserted in the same manner as the coil in slot *12* already described, but is not taped or shaped until its other side is threaded into slot *11*. The ends are then taped from iron to iron with treated tape, which overlaps and seals the projecting end of the insulating cell. This in turn is covered with a layer of cotton tape. The lower part of the coil is then shaped with a rubber or rawhide mallet and fiber drift and is treated with an insulating compound before the next coil is wound in place. The drift and mallet used in shaping the coils should have their sharp corners smoothed off,

and in no case should the coils be struck directly with an iron tool. Fig. 58 is a partially wound stator, showing the finished shape of the coil ends. It is particularly necessary that both tapings should be applied as tightly as possible, as a failure to watch this point will result in the taping becoming loose and baggy when shaped. This is especially true if the slot is very deep as the process of dipping or shaping the bottom coil below the bottom of the slot has a tendency to pull the tape away from the laminations. To avoid this tendency it is desirable to us glue on those turns of tape that cover the projecting ends of the fish paper cell.

During the operation of taping, the beginning and end of each coil should be brought out in such a manner as to lie on the side of the winding farthest from the bore of the stator and so placed that the beginning of one coil faces the end of the adjacent coil in a manner convenient for connecting. The method of winding just described is continued until all the coils are in place. The winding is completed by placing the top parts of the throw coils in their respective slots. A completed stator is shown in Fig. 59.

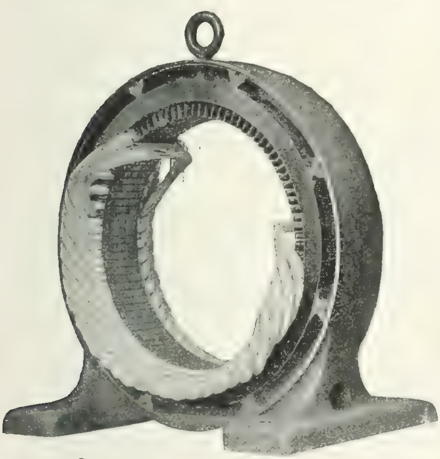


FIG. 58—PRIMARY PARTLY WOUND WITH BASKET COILS

Threaded Diamond Type—Two Coils Per Slot—The threaded type of diamond coil is wound of treated wire, either on a mould, which finishes the coil to shape, or on a shuttle which winds the coil first in the shape of a loop, after which the loop is placed in a universal former; the two straight sides are clamped between suitable jaws and are pulled apart a definite distance, the coil assuming the shape shown on the right in Fig. 55. This type of winding is similar to the basket winding just described in so far as the slot is insulated instead of the coil. On the other hand, the structure and the shape of the finished coils is identical with that of an open slot insulated coil. It is, therefore, not necessary to shape the coil after it has been placed in the slot as in the case of the basket winding. The slot insulation is practically identical with that of the

basket winding with the addition of a fiber center strip to separate the upper and lower coils in the same slot. In this case, however, the slots are laid out in groups according to the winding diagram, the number of groups being equal to the product of the number of poles by the phase of the motor. This grouping may either be uniform, alternate or irregular, according to the design of the winding. When the grouping is uniform, all groups consist of an equal number of slots, and contain an equal number of coils. In alternate grouping, every other group contains an equal number of slots and coils. In irregular grouping there is no apparent uniformity in the number of slots and coils per group.

In preparing to wind the machine, the slots forming the beginning of each group are marked to indicate that the coils to be placed in them must be furnished with additional insulation at the ends. This is necessary as these coils form a boundary between phases, and consequently are subject to phase potential, whereas the potential between any other two adjacent coils is much less.

FIG. 59—COMPLETED BASKET WOUND STATOR

Taking as an example a *72* slot, six-pole, three-phase motor with a throw of *1* and *11*. There will be $6 \times 3 = 18$ groups of four coils each, with 18 taped phase coils in the winding. The winding of the coils into the slots is begun by threading the bottom of the first coil into slot *11*, the upper half of the coil being left up as a throw coil. The bottom parts of the next nine coils are inserted in rotation, thus making ten coils left up as throw coils. The succeeding coil is placed in two slots, *11* and *21*, the rule being that no upper part of a coil shall be placed into a slot the lower part of which is empty. After each bottom coil has been threaded into its cell, both cell and coil are raised to the top of the slot and the projecting sides of the cell are cut off as close to the laminations as possible. The coil is then forced back to the bottom of the slot. The edges of the insulating cell are folded over

each other and held in place by the fiber center strip. The latter should be of a width to make a driving fit in the slot so as to hold the lower coil and cell firmly in place, and should be long enough to project out of the slot beyond the straight part of the coil.

Every fourth coil, in the present case, is one of the special phase coils, and is taped at the end from iron to iron with an overlapping layer of insulating tape and a protective layer of cotton tape. The remaining coils are left without any special insulation at the ends. Fig. 60 shows a partially completed diamond coil winding with the workman threading a coil into a slot.

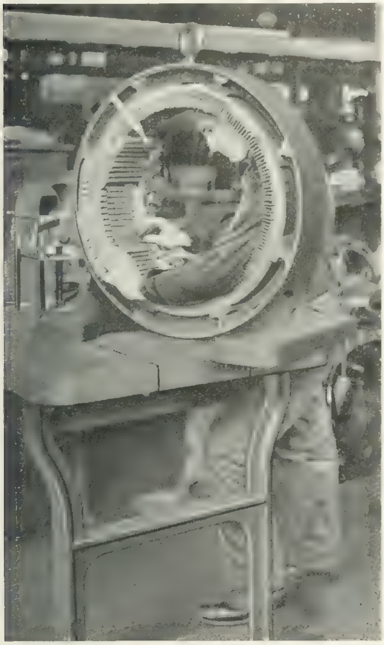


FIG. 60—INSERTING DIAMOND COILS, PARTLY CLOSED SLOTS

The placing of the upper part of the coil in the slot requires more care and skill, since the remaining space in the slot is just large enough to receive the coil with its wires lying parallel to each other. Fig. 54 shows the cross-section of a coil three wires wide by four deep, the wire being threaded through in such a way that wire *1* is first passed through the slot, then *3* and finally *2*. This is continued with each succeeding layer until the whole coil is in place. The cell is then folded in and the slot closed with a fiber wedge. The two coils must completely fill the slot. If the insulation already mentioned is not sufficient to do this, additional filling strips of fullerboard, or treated wood, are packed into the bottom or sides of the slot as may be required, until the coil is tight enough to prevent movement in the slot. The upper and lower parts of the winding outside of the slots are carefully insulated from each other by a strip of treated duck cloth. This strip should be wide enough to extend from the fish paper cell to the portion of the coil farthest away from the slot, and is threaded between the ends of the coils as they are inserted in the slots. Fig. 61 shows a completely wound stator of this type.

OPEN SLOT WINDINGS

The distinctive difference between the coils for a partially closed slot and an open slot winding, is that the latter are completely insulated before being inserted in the slots. They may, therefore, be wire or bar formed, and can readily be insulated for any commercial voltage. Consequently, motors of large size, or for voltages exceeding 550 volts are nearly always of the open slot type. The insulation over the coils consists of a cell of treated cloth or mica over the straight part, and an overlapping layer of cotton tape over the whole coil. The extra insulation for the high voltage machines is made up by extra thickness or extra turns of the insulating cell. The phase coils receive an extra wrapping of treated cloth tape over the diamond ends in addition to the cotton tape, which, as a distinguishing mark, is of a special color on these coils. After the final wrapping is completed, the coils are dried in a moderate temperature in order to expel all moisture, then, while still hot, are dipped in an insulating compound and again subjected to moderate heat until the compound is thoroughly dried. This compound serves to fill up all the pores in the insulating materials and make the coils dust and moisture proof.

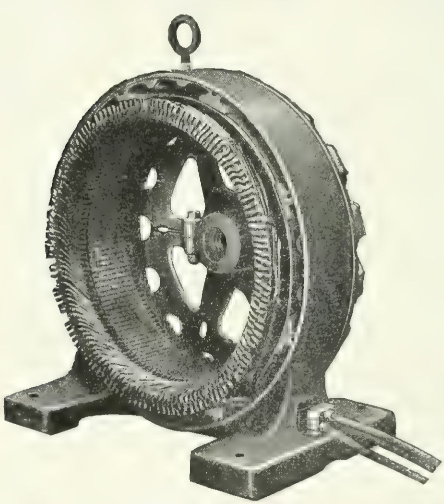


FIG. 61—COMPLETED DIAMOND WINDING, PARTIALLY CLOSED SLOTS

Before inserting the coils in the slots the latter are lined with cells of paraffined fish paper cut wide enough to project out of the top of the slot when folded, and serve as a guide to the coils. These winding cells are to furnish mechanical protection only to the coils.

Assume a stator designed for six poles, 72 slots, two-phase, with a throw of *1* and *12*. The total number of groups with uniform grouping being equal to the product of the number of poles by the phase of the motor, in this case will be 12, with six slots each. The groups are laid off in a clockwise direction, the outside

slots of each group being marked to receive phase coils, of which there are two per group. The coils are inserted in regular order, beginning with the bottom part of a phase coil in slot *12*, and inserting phase coils wherever indicated. They are driven into place by means of a fiber drift and mallet. Paraffine may be used as a lubricator, if necessary, as the coil should be a good driving fit in the protecting cell. The top parts of the first eleven coils, which are to be the throw coils, are inserted only temporarily until the bottom coils have been inserted into these slots. Fig. 62 shows these throw coils as first inserted, and Fig. 63 shows the same coils with the upper part raised out of the slot to admit the corresponding lower coils. The remaining coils are driven tightly into place, the projecting edges of the winding cell are trimmed off close to the core, and folded in, and the slot is closed by driving a fiber retaining wedge into the grooves at the top of the slot. In some machines this wedge covers the entire face of the coil, while in others short wedges are driven in at each side, leaving the coil exposed at the middle of the core.

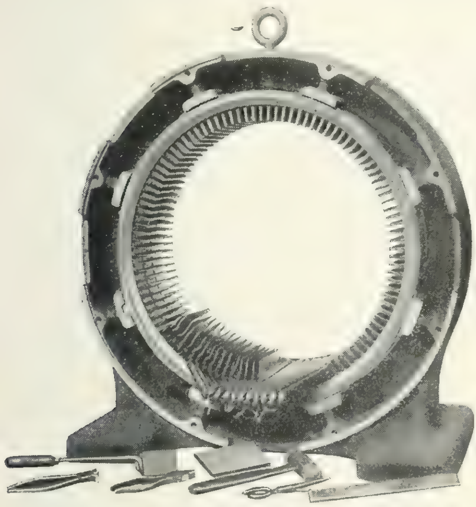


FIG. 62—DIAMOND COIL OPEN SLOT STATOR, PARTLY WOUND

TESTING

After all the coils are in place on either of the types described, the winding is carefully inspected for mechanical defects. All coils must clear the bore of the stator by at least one-sixteenth of an inch, and any coil which obstructs the bore should be tapped down with a mallet and fiber drift to give the allowed clearance. All cells must be intact and sound, especially at the bottom of the slots. If the punchings have been spread apart by driving in the fiber wedges, they must be closed up again. The punchings should also be inspected to see that no fragments project into the bore of the stator where the rotor will rub against them.

The winding is then subjected to a break-down test to make sure that the insulation is sound at those points which in service will receive the most strain; i. e., from coils to iron, and from phase to phase. All coils of the same phase are connected together by a piece of copper wire. The terminals of a testing transformer are then connected between the different phases and from each phase to iron and the required voltage is applied for a length of time depending upon the characteristics of the machines. In case this test punctures the insulation of any coil or the insulating cell in any of the slots, this insulation must be removed and replaced.

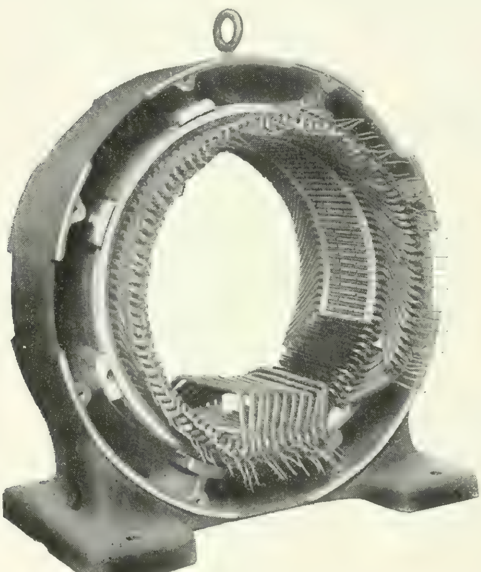


FIG. 63—DIAMOND COIL OPEN SLOT STATOR, WITH THROW COILS RAISED

If the puncture occurs in a top coil, it may sometimes be repaired by raising the coil out of the slot, removing the punctured insulation, and carefully replacing it with new material. If, however, a bottom coil or cell is punctured, it must be removed by raising the tops of the overlapping coils. The same procedure must be followed if a coil has to be replaced, as in the case of a burn-out due to a short-circuit. Such a process amounts practically to retracing the operation performed in the original winding until the injured coil is exposed.

In repair work where only one coil of a basket winding is burned out or damaged, and in general if the coils have been painted and are stiffened, rather than to remove all the throw coils, it is frequently easier to thread in a new coil. To do this cut the damaged coil at each side of the core and pull the wires out. New fish paper and treated* cloth cells are inserted and the adjacent coils bent

*In emergency, fullerboard or rope cement paper may be used in place of fish paper. The treated cloth is variously known as treated cloth, oiled linen, empire cloth, etc.

slightly to get them out of the way, as shown in Fig. 64. Double cotton covered wire of correct size and suitable length for rewinding is obtained and rubbed with paraffine. If the coil consisted of two or more wires in parallel, that number should be used in rewinding. The number of wires in parallel is the number entering a given coil from any junction point of coil terminals. The wire or wires in parallel are then threaded through the space previously occupied by a coil as shown by Fig. 65. Great care must be exercised during this process to see that all the wires lie parallel in the slots and are kept free from kinks. Otherwise, it will be impossible to get the full number of turns into the slot. In case of a large number of turns, say more than 20 per slot, two or more

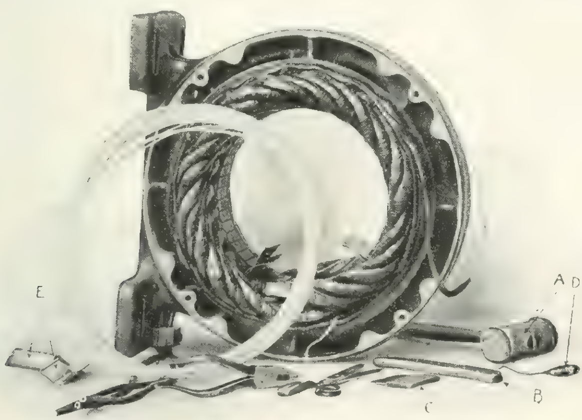


FIG. 64—BASKET WOUND STATOR WITH DAMAGED COIL REMOVED

lengths of wire may be wound at the same time and connected in series after winding, the joint being made outside of the slot. When the required number of turns have been inserted, the edges of the cells are trimmed and folded in, the coil is wedged in place and taped as described above.

CONNECTING

After the ground test the coils are connected into groups, by joining together the beginnings and ends of adjacent coils until the group has but one lead at each end unconnected, which form the leads of that group. In doing this, the wires are scraped clean and a sleeve connector of tinned copper is slipped over them after which they are soldered and taped. If suitable connectors cannot be obtained (as may occur in making repairs), the stubs may be wrapped with fine bare copper wire and then soldered.

The terminals of the various groups are next connected into proper phase relations with double braided rubber covered wire or cable, the size of wire and the grade of insulation depending upon the current and voltage. Joints in cables or wire larger than No. 6 should be made by wrapping with fine bare copper wire. Great care must be taken while connecting and soldering joints to protect the winding from the molten metal. After soldering, all joints and splices are rubbed smooth with emery cloth, insulated with treated cloth tape, covered with one of more layers of cotton tape, and sat-

FIG. 63—INSERTING NEW COIL IN DAMAGED BASKET WOUND STATOR

urated with an insulating varnish or shellac. The connecting cables are arranged over the end of the windings in such a manner as to occupy the least possible space and yet keep clear from the frame or end brackets, as shown in Fig. 61.

The following points should be carefully watched in order to make a good job of connecting:—

1—All wires should, if possible, be tinned before the connectors are put on. If this cannot be done they must be thoroughly cleaned by scraping.

2—Soldering must be well done, making a smooth and solid joint.

3—The wires of the joints should lap if space permits.

4—No acid flux should be used.

5—The wires or cables must be arranged in such a way as to occupy the least space and not obstruct ventilation.

6—Wires or cables must be clamped or tied down to avoid vibration.

7—Joints must be carefully insulated.

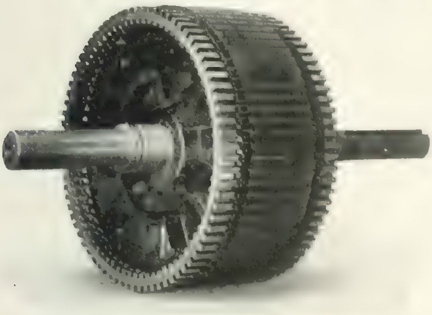


FIG. 66—SQUIRREL CAGE ROTOR WITH LOW RESISTANCE END RINGS

After connecting, the winding is tested for electrical balance by causing a current to flow through it and comparing the voltage and current readings of each phase.

The windings on the side on which the connections are made, usually called the front side, are as a rule more rigid than those on the rear side, due to the fact that the connections exert a bracing effect. Since the windings in the rear lack this bracing effect, it is usually necessary with diamond windings to supply a supporting ring of insulated steel to which all the coils are laced with rope made of six or eight-ply waxed ends. The inside diameter of this ring should be just large enough to make a good fit over the winding. If it is much larger than that of the winding, the coils will be under tension which will in time tend to loosen them from the supporting ring. Care should be exercised in lacing the coils to the ring, when the rope is led through ends of the coils with a steel needle to see that no damage is done to the insulation.

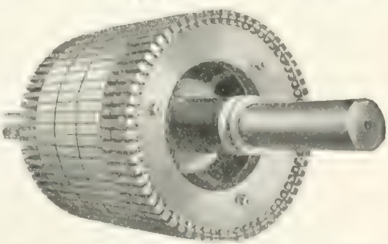


FIG. 67—SQUIRREL CAGE ROTOR WITH HIGH RESISTANCE END RINGS

Cleats and Terminals—The cables that tap into the winding and extend to the outside of the frame are called lead cables. To avoid the possibility of these cables transmitting jerks and vibrations to the soldered joints of the winding, they are fastened to the frame by iron or porcelain cleats. Such cleats are also supplied

to support the cables from sagging wherever they pass close to the iron or moving parts.

Painting—After the winding and connecting is finished, all of the windings, and especially the taped joints, are thoroughly brushed with shellac or a finishing varnish. This material seals up any porous places in the insulation, thus excluding dirt and moisture.

INDUCTION MOTOR SECONDARIES

The squirrel cage secondary is the simplest mechanically, and at the same time is the most rugged and compact form of moving element to be found in any electric motor. It can be constructed very cheaply, and consequently is used whenever applicable. The operating characteristics of a squirrel-cage rotor are dependent on its resistance. A winding of low resistance will have good efficiency and small slip, but will have poor starting torque for a given maximum current. A winding of high resistance, on the other hand, will have lower running efficiency, and large slip, but will give a high starting torque with minimum current, and is suitable for mill or crane work where starting under heavy load is frequent and operation is for short intervals only. Where it is necessary, however, to start a heavy load with small starting current, and operate for long intervals with good efficiency, or wherever it is necessary to vary the speed or operating characteristics of the motor from time to time, a wound secondary should be used. The windings have a low resistance, and are connected in star with the open ends connected to slip rings. Adjustable external resistance can then be connected in series when starting, after which the rings can be short-circuited.

SQUIRREL CAGE SECONDARIES

A completed squirrel cage rotor of the low resistance type is shown in Fig. 66, and a rotor with high resistance end rings is shown in Fig. 67. There are many styles of both general types, but these may be taken as typical illustrations of modern rotors.

The core is built up of laminated steel on a spider of appropriate shape, and keyed in place with a feather key on the spider and ring keys at the ends. Ventilators are seldom used except on the wider cores, intended for the mill type motors. The slots are of the partially closed type.

Bars—Rectangular copper bars are cut from soft drawn bar stock. They are placed in a jig and drilled with exact spacing of

the drill holes, to correspond with those in the end rings. The burred side of the hole is countersunk, the holes are threaded, and the side of the bar which goes against the ring is ground to a true surface. The bars are cleaned from oil, etc., by dipping them in a solution of potash lye and rinsing them in hot water. A rope-paper cell labout an inch longer than the core is glued around the bar for insulation.

End Rings—The end rings are made of copper, brass, or various grades of resistance alloys. The form shown in Fig. 66 is cut from a long, hollow cylindrical "pot," which is cast considerably thicker than is absolutely necessary in order to provide sufficient material to allow the outer surface to be machined off, thereby obtaining homogeneous metal, free from blow holes. The pot is turned in a boring lathe to exact inner and outer diameter. This is of extreme importance, as the bars will not make contact with the full width of the ring unless the external diameter is exactly correct. The rings are then cut from this pot. The resistance of the ring, and consequently the characteristics of the motor, depend upon both the width and thickness of the ring, as well is its composition, and may be varied over a wide range by changing these dimensions. The rings are then mounted in a jig consisting of a ring of steel large enough to fit over the end ring, with rows of holes evenly spaced around it, conforming to the slot spacings. By guiding a drill through these holes in succession, exact spacing of the drill holes is insured. The burred ends of the holes are slightly countersunk and the outer surface of the ring is buffed to a true surface.

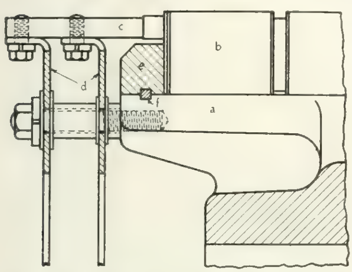


FIG. 68—SECTION OF HIGH RESISTANCE ROTOR, SHOWING
a—Rotor Spider.
b—Laminated Core.
c—Conductor.
d—Resistance Rings.
e—End Ring.
f—Ring Key.

Before inserting the bars, the slots are cleaned of all foreign matter and inspected carefully for defects. The bars are then driven into them to approximately their final position, and end rings are slipped into position. Three or four bars, equidistantly spaced, are screwed to the rings, small brass or steel distance pieces being held under screws and projecting against the core on

each side to preserve equal spacing at each end of the core. The other bars are then screwed to the ring, lock washers being placed under each screw. The rotor is next mounted in a lathe, the ends of the screws are turned off, and the body of the core turned down to exact diameter. The screws are again tightened, and center-punched to rivet them in place. The contacts may or may not be soldered. Blowers are next mounted on each side of the rotor. As cooling surface to dissipate the heat generated. The contact surfaces between the bars and the rings are well tinned, but no solder a last operation the secondary is balanced for static balance, and is no wready for assembly.

End rings of the form illustrated in Fig. 67 are made of sheet brass or copper, having teeth as shown in Fig. 68 bent over and bolted to the bars. The thin flat shape furnishes considerable

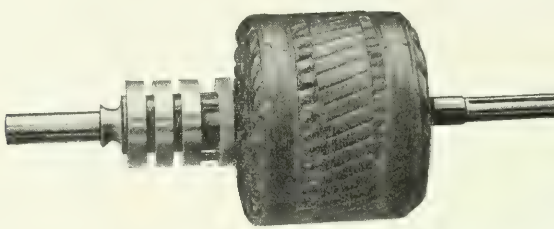


FIG. 69—THREE-PHASE ROTOR WITH BASKET WINDINGS

resistance, and also affords a large cooling surface to dissipate the heat generated. The contact surfaces between the bars and the rings are well tinned, but no solder is used, so that no harm can result from overheating. The end rings are securely fastened to each end of the rotor by heavy stud bolts threaded into the spider or rotor end plate. They are, of course, grounded onto the spider by these bolts, but these grounds do not affect the operation of the motor.

PHASE WOUND SECONDARIES

Wound secondaries may have either diamond or basket coils. They nearly always have partially closed slots, and quite freqeuently the slots are skewed, to prevent noise. The wire wound coils are inserted in a manner similar to the wire wound threaded-in coils for direct-current armatures. The slots are insulated with fish paper and treated cloth cells, and the throw is determined by the number of slots per pole. The coils in each group are connected

in series, and the groups of each phase are ordinarily connected in series. The phases are connected in star. Wedges are inserted to hold the coils in the slots, and the rotor is banded and balanced in the same manner as a direct-current armature.

In the larger machines, the coils are generally former wound, of strap copper, and are completely insulated before insertion in the slots. Where the partly closed slots is employed the complete coil is composed of several straps, each completely insulated with a wrapper of treated cloth and a winding of cotton tape. In some types of machines, designed for especially heavy service, the insulation is composed of sheet micanite, wrapped with cotton tape.

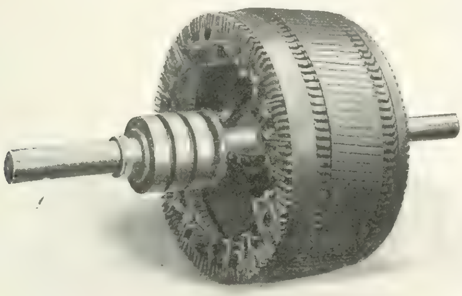


FIG. 70—THREE-PHASE ROTOR WITH DIAMOND WINDINGS

A cell of fish paper is inserted in the slot for mechanical protection and the straps are threaded in one by one. The cell is then folded in and a wedge inserted. Figs. 69 and 70 show completed rotors of the basket and diamond coil types respectively.

The collector rings are of copper or brass. If mounted inside the bearings, they are usually provided with lugs which are bolted through insulating washers to a ring in a small spider. If mounted outside the bearing, the leads are brought out through the hollow shaft and bolted to the rings.

NOTES ON CONDUCTORS FOR HEAVY ALTERNATING CURRENTS

K. C. RANDALL

WHILE problems involving direct-current circuits may be solved by the use of Ohm's law, such is not the case when alternating currents are used, as the simple resistance of the conductor is not the only impediment to the passage of current. Self-inductance must also be considered, as in some cases it, rather than the resistance, limits the flow of current, the real impedance value of the circuit being determined by the vector sum of the ohmic and inductive drops. The self-induction of a circuit is influenced by its dimensions and shape, and sometimes by the shape of the conductors, although this consideration is not ordinarily of importance. Changes in frequency also correspondingly change the value of the self-induction. For purposes of comparison, the self-induction of a single conductor of ordinary shape may be said to vary inversely as the length of the contour of its cross-section. Similarly, the mutual induction betwen conductors will roughly vary inversely as the distance between them.

A single, large, solid conductor will carry a direct current with a uniform density throughout the whole section, that is, all of the conductor is equally useful, but this is not so for alternating current. If a solid conductor be considered as made up of a number of insulated concentric tubes of equal section, they will all have equal resistances, but the self-induction of the innermost unit will be larger than that of the outer ones in approximately the inverse ratio of the lengths of their perimeters and consequently the outer areas will have a lower impendance than the inner ones. It is therefore apparent that the current will not distribute itself uniformly throughout the several concentric equal conductors, but will favor the outer sections. This surface distribution of current is called "skin effect."

Consider two parallel conductors of an alternating-current circuit. When current flows in one of the conductors, a magnetic field exists around it and part of this magnetic field encloses the second conductor. This field induces a voltage in the conductor which *opposes* the flow of current and also a voltage in the second conductor in the *same* direction. But the return current in the second conductor is in the opposite direction and, therefore, is favored by this voltage. Now the nearer portions of the second

conductor are more influenced by this magnetic field than the farther portions and the consequent tendency is for the current to favor the adjacent portions of the two conductors inasmuch as it is there that the induced voltage, assisting in the flow of current, is maximum. This mutual inductive action between the conductors results in the concentration of current in the adjacent areas and has the same influence in reducing the effective conductivity of a conductor, as is observed in a single conductor due to the relative self-induction of the inner and outer sections.

Skin effect, therefore, is the result of the combined influence of mutual and self-inductance of the conductors. At ordinary commercial frequencies, small conductors do not experience skin effect, but as conductors of increasingly large size are considered, the surface distribution of alternating current becomes more pronounced and the increased losses due to skin effect grow in importance. The skin effect on one-half inch and even one inch conductors on a 25 cycle circuit is negligible, but with a two inch conductor, the effective resistance has been increased more than 25 percent, due to the skin effect. Similarly for 60 cycles, the one-half inch conductor experiences a trifling increase in the effective resistance, the one inch conductor an 11 percent increase and the two inch conductor an increase of more than 80 percent Furthermore, this increase is independent of the current density which is employed. A two inch copper rod (at 20 degrees C.), 78 feet long will carry 5 000 amperes, direct current, with an ohmic drop of one volt and an energy loss of 5 000 watts With a 25 cycle current of the same volume, the ohmic drop would be 1.26 volts and the energy loss 6 300 watts; with 60 cycle current, 1.82 volts and 9 100 watts loss.

These considerations would lead one to infer that for 60 cycle service it would practically be necessary to double the conductor section and for 25 cycles to increase the section about 25 percent in order to secure direct-current conditions. This conclusion, however, is misleading, for if the two inch conductor be increased 82 percent in section, the effective resistance of the conductor to 60 cycle current will still be about 25 percent greater than the original two inch conductor, to the passage of direct current.*

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*For tabulations of increase in resistance values see the various electrical handbooks.

Fortunately, there are means of improving the conductivity of heavy conductors even for fairly high frequency alternating current without the excessive increase in section, as outlined above. From the consideration of self-induction and the tendency to surface distribution, it would appear that the center portion of a conductor might be removed without appreciably impairing the effective conductivity for alternating-current. This is true, but on account of the influence of mutual induction between adjacent conductors, the hollow tubular conductor does not have all the advantages which might be attributed to it at first thought. Obviously some arrangement of the elementary conductors into which large units may be considered as sub-divided, such that each elementary circuit bears the same relation to all others within the same conductor, as well as to those of the adjacent conductors, as will make the impedances equal and, therefore, the current distribution will be uniform, which is the condition desired. In practice such an arrangement cannot be carried out conveniently and approximations must suffice. It is usual to employ stranded cable, interlacing the conductors from opposite sides of the circuit. Sometimes bars of copper strap from opposite sides of the circuit are interlaced in this way if the currents are very large.

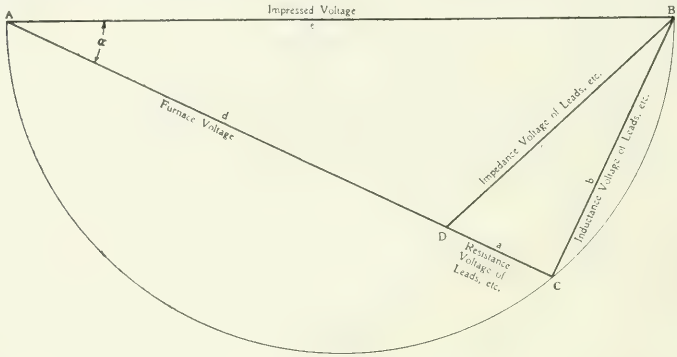


FIG. I

One of the most common uses of large alternating-currents is for electric furnace work where currents running into many thousands of amperes are commonly employed. The design of the conductor system for a large furnace becomes quite a problem and even after installation it is usually necessary to determine the conditions under which maximum output may be secured.

The conditions of maximum energy may be determined as follows: By referring to Fig. 1 it may be seen that the area of the triangle *ABD* and likewise the energy of the circuit corresponding to the triangle, will be a maximum when side $d =$ side c. $\cos \alpha = \frac{d+a}{e}$ and when $d = c$, $\cos \alpha = \frac{e}{2d}$

Hence $\frac{d+a}{e} = \frac{e}{2d}$ and $e = \sqrt{2(d^2 + da)}$.

Thus, $\cos \alpha = \sqrt{\frac{2(d^2+da)}{4d^2}} = 0.71 \sqrt{1 + \frac{a}{d}}$

Or, since $d = c = \sqrt{a^2 + b^2}$, $\cos \alpha = 0.71 \sqrt{1 + \frac{a}{\sqrt{a^2+b^2}}}$

which is the value of the power-factor for maximum input to the furnace.

If the operating frequency were increased, it would be necessary, in order to secure maximum input, to increase the resistance of the furnace until the line *d* and *c* again become equal. It would then be found that the input at the new frequency would have changed practically in the inverse ratio of the frequency. (This would be exactly true were the resistance of the leads, etc., zero.)

The influence of change of voltage is the same as in direct-current work, and therefore the input varies as the square of the voltage.

It may be noted that the maximum input to the circuit (leads and furnace) occurs when adjusted for a power-factor of $71 \sqrt{1 + \frac{a}{\sqrt{a^2+b^2}}}$ percent. When the resistance *a* of the leads is negligible the power-factor becomes approximately 70 percent. Obviously the design of the furnace circuits is of great importance as they determine the conditions of operation both as to maximum input and as to power-factor. While it is true that the point of maximum input from a constant voltage circuit is at a power-factor of about 70 percent, the conclusion should not be reached that a power-factor of 70 percent is most desirable, because in general, this is not the case, as the higher the power-factor the more satisfactory is the operation of generators, transmission lines and transformers from which the furnace current supply is derived.

ELECTRIC POWER FOR RAILROAD OPERATION*

F. DARLINGTON

THE results obtained by the use of electric motive power on existing railroads have demonstrated that it has certain advantages over steam power. These results, however, do not fully indicate these advantages because electric railroads have not had equal opportunities with steam railroads. In the first place, steam railroads were well established and in successful operation and occupied all of the best territory long before electric railroads were developed; second, electric railroad apparatus has only recently reached a state of development where it is economical to install and operate for all kinds of railroad work, and even now it is not economical under all conditions; third, steam railroads (especially well-estabished and successful roads) get money at much lower rates of interest than newly-projected electric railroads do; and fourth, steam railroads have in their organizations some of the ablest and best-trained men in the country, who have grown up with the business, while electric roads have generally been in the hands of far less experienced men.

Electric railroads have, nevertheless, been successful for certain classes of work, especially in well-settled and prosperous sections. But in nearly every instance such sections were previously provided with steam railroad accommodations. Electric roads, in order to pay their fixed charges and earn a profit, especially where they compete with steam roads, must give improved accommodations. They serve the public by giving more convenient and cheaper local passenger accommodations than steam railroads; they so greatly improve local passenger accommodations that where they directly parallel steam railroads it is customary for them to earn, in competition with the steam railroads, two to four or more times as much as the earnings of the steam railroads from local business. Also, they carry passengers at a low rate of fare. Two cents a mile passenger laws have no effect on them, as their rates are generally in the neighborhood of one and one-half to one and three-quarter cents per passenger-mile. It is not intended to imply by this statement that one and one-half cents, or even two cents a mile is a fair passenger-carrying rate for average railroads. Take, for example, states, of which

*Based on a lecture delivered before the Richmond Railroad Club

there are several, where there are between one thousand and two thousand miles of electric railroads and in the neighborhood of ten thousand miles of steam railroads. In these states the electric roads are only in the best territory, where the travel is dense, and they can carry passengers at a lower cost per mile than steam railroads, which have to make substantially uniform passenger rates over thousands of miles of road, on many miles of which the passenger travel is so light that it is unprofitable, excepting as it feeds other sections.

The electric railway companies are just beginning to learn the freight business. Their promoters and managers heretofore knew little about freight traffic and paid little attention to it. This is changing. They find that because of their convenience and economy for light local work they can originate and build up both freight and passenger traffic. They hold the key to much of the first-hand business, which is non-competitive, or the business that originates and terminates with the customer at the smaller local points.

THE COMMERCIAL ASPECT OF THE ELECTRIFICATION OF RAILROADS

Any useful comparison of the earning power of electric and steam railroads must take into consideration not only the difference in operating costs but also the difference in gross earnings, and the increase in net profits, if any, secured by the use of electric power must be balanced against the fixed charges for the increased cost of electric equipment before the net result is deduced. In this connection, where steam roads are electrified, there should be subtracted from the cost of electrical equipment the value of the steam locomotives, and of the coal cars used for carrying locomotive fuel, which are released from service by the installation of electric power; also the savings in water stations, round houses, and many minor items.

The different kinds of service—freight and passenger, long and short haul, dense and scattered traffic, competitive and non-competitive, etc., and numerous other things that make up steam-railroad conditions, are all differently affected by railroad electrification.

SYSTEMS OF ELECTRIFICATION

There are three distinct electric railroad systems in use. The direct-current system is the oldest. The other two are the single-phase and three-phase alternating-current systems. They are radically different in essential particulars, and in the results that can be accomplished with them. Heretofore electric railroads have been largely equipped with direct-current apparatus. Excepting

where conditions other than commercial advantages or economy of operation prevailed, this system in America has not been much applied to moving heavy trains long distances. The most notable examples of its use in this country for moving heavy trains are for short distances, as on the New York City terminal of the New York Central Railroad, where it was installed to avoid smoke and to improve the service in the tunnel, and also in the Baltimore & Ohio Railroad tunnel, at Baltimore. On one of the Camden-Atlantic City lines of the Pennsylvania Railroad there is a multiple-unit electric car service, where several passenger cars are operated together in motor-car trains. These trains are run at high speeds by the direct-current system, using a third rail.

The principal things that have stood in the way of more general use of the direct-current system for heavy traffic have been the high cost of construction and the low efficiency of the electric power distribution. Both of these items are improved by the new high-tension alternating-current systems. Both have their advocates, but they will seldom come into competition, except in academic discussions, because they are not generally suited to do the same kind of work under the same conditions.

In America there are over twenty railroads using the single-phase system. Three of them are handling main-line railroad traffic, using heavy electric locomotives. They are the New York, New Haven & Hartford Railroad, operating with electric power between Stamford and New York City; the Grand Trunk Railroad, operating with electric power in Sarnia tunnel, between Port Huron and Sarnia; the Spokane and Inland Railroad, conducting a combined freight and passenger business over 115 miles of road.

In the single-phase system high tension alternating currents are supplied to the locomotives, or motor cars, directly from overhead trolley wires. The potential commonly employed on single-phase trolleys in America is either 11 000 volts or 6 600 volts, the high-tension current from the trolley being transformed to low potential by means of transformers on the trains, where the low-potential current is used directly by the motors.

The distinguishing characteristics of this system are:

Large powers are easily and cheaply transmitted and distributed to any point along the railroad track without the use of sub-stations requiring moving machinery and attendants.

The losses in power transmission and distribution and the leakage or standby losses are small.

There is only one place in America where the three-phase system has been installed. This is on the Great Northern Railroad, where heavy three-phase electric locomotives were supplied for hauling main-line freight and passenger trains through the Great Northern Railroad tunnel in the Cascade Mountains, a distance of about four miles.

COMPARATIVE OPERATING CHARACTERISTICS OF STEAM AND VARIOUS TYPES OF ELECTRIC LOCOMOTIVES

Most steam locomotives will maintain a stronger draw-bar pull when moving slowly than when going rapidly. In general, they will not maintain their maximum draw-bar pull at speeds of more

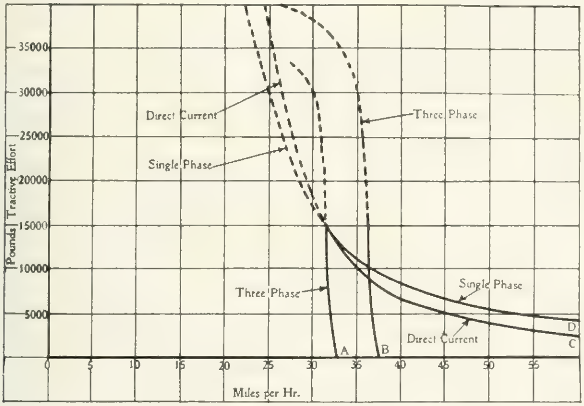


FIG. I—APPROXIMATE CURVES SHOWING RELATION OF TRACTIVE EFFORTS AND SPEEDS OF ELECTRIC LOCOMOTIVES

A—Three-phase of same continuous capacity as single-phase and direct-current shown.

B—Three-phase to give same service as single-phase and direct-current on the particular run and profile used.

than eight or ten miles per hour for freight and about fifteen miles per hour for passenger locomotives. On steam locomotives designed for freight service, if the speed is increased from fifteen to thirty miles per hour, the pull that they can continuously exert is generally reduced by half. In the case of passenger locomotives, the continuous tractive power is decreased about half by an increase of speed from twenty to forty miles per hour, and for steam locomotives in general, through quite a wide range of speeds, the tractive power that they can exert continuously is about inversely proportional to their speed.

With electric locomotives, the variations in tractive power, with changes in speed, are very different. The curves shown in Figs. 1 and 2 are designed to show the tractive effort that electric and steam locomotives, respectively, can exert at various speeds. Curves *A, C* and *D* represent electric locomotives of the same continuous capacity, while curves *B, C* and *D* represent the characteristics of machines to perform the same service on a particular railroad division. For the particular division considered, the grades are of such character that the locomotives must work at their continuous capacity for considerable periods.

Curves *A* and *B* are for three-phase locomotives, curve *A* at the same speed as the direct and single-phase locomotives when operat-

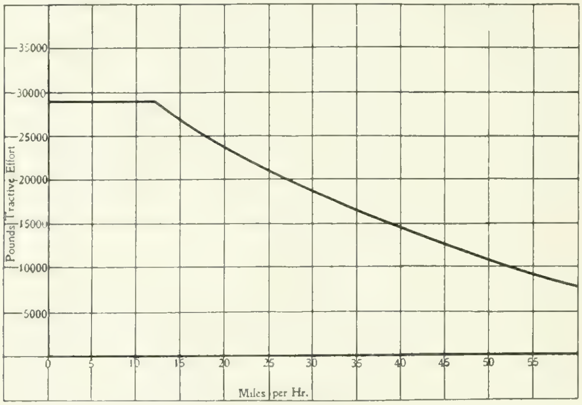


FIG. 2—APPROXIMATE CURVE SHOWING RELATION OF TRACTIVE EFFORT AND SPEED FOR STEAM LOCOMOTIVE

ing at their continuous capacity, and curve *B* representing a locomotive designed for a higher speed and greater power, which will be necessary with the three-phase locomotive to meet the same requirements of schedule as the other types of electric locomotives, when operated on the particular railroad division for which the locomotives were designed. A higher running speed is necessary for the three-phase locomotive than for the other locomotives at their continuous capacity rating, because three-phase locomotives cannot take advantage of light grades to run at high speeds as can direct-current and single-phase locomotives.

For three-phase locomotives the relation of speed to tractive effort is entirely different. Three-phase locomotives operate with best efficiency only at substantially constant speed. By introducing

certain devices and connections half normal speed and double normal speed and good efficiency may be obtained. At constantly varying speeds these motors are inefficient, and no matter how light the grade or load, three-phase locomotives cannot pull a train faster than a certain predetermined speed.

Of the two alternating current systems, the single-phase system is the most generally applicable to the widely varying conditions of transportation. It is suitable alike for light and heavy trains, for fast and for slow speeds, for variable speed with frequent stops, or for constant speeds for infrequent service scattered over long distances, or for heavy service concentrated within short distances, for switching and making up trains, etc., to meet all the needs of railroading. The three-phase system is especially well suited for one class of railroad work only, namely, hauling heavy trains at constant speed and constant tractive effort, but it is not so well suited as the single-phase system to meet the various other needs of railroads.

COMPARISON OF OLD AND NEW SYSTEMS

Every complete railroad electrification equipment includes three principal parts:—

A central station plant for generating power.

Electric conductors and apparatus for transmission of electric power from the central station and its distribution to the moving trains.

Electric motive power apparatus for the conversion of electric power on the train to mechanical power for train propulsion.

Central Station Plant—Under ordinary conditions, the cost of the power plant is something over one-quarter of the total cost of steam railroad electrification. The power plants for the three systems are very similar in their essential parts, the principal difference between them being in the total amount of electric power required by the three systems for the same train service.

In electric railroads operating power is needed to supply the losses in transmission and distribution of electric power; the losses in electric motors and machinery on trains, and power for moving trains. Losses in transmission and distribution are of two kinds. Certain losses, including those in the copper conductors and third rail, etc., occur practically only when trains are taking electric power from the lines, and are heaviest when the greatest total power is being taken from the train. Accordingly, the power-house is called

upon to supply these losses in greatest amount at the time of heaviest power demand, and power-station capacity has to be provided for them; but since railroad power demands are usually very fluctuating and very heavy power output is usually of short duration, the average of these losses is small, even though their momentary maximum may be large.

In addition to these transmission and distributing losses, there is another set of losses that are constant as long as the lines are charged with current and ready to deliver power to trains. They include leakage, losses in transformers, and iron losses, exciting current, etc. They are never very heavy at any paticular instant, and hence do not add greatly to required horse-power capacity of the power plants, but they are constant in their operation and consume a proportionally large total amount of power. These constant losses are the cause of great aggregate loss in most direct-current electric railroad systems, but are generally small on single-phase systems. In a paper read before the Indiana Electric Railway Association, January, 1905, Mr. A. S. Richey gives the average losses between the generators and the cars on direct-current trolley roads in Indiana as follows:—

Step-up transformers	6 percent.
Transmission lines	3 percent.
Step-down transformers	7 percent.
Rotary converters	20 percent.
Direct-current distribution	20 percent.

The total average loss as above is 56 percent of the output of the generators.

In the alternating-current systems, rotary converters or motor generators are not used, and the losses in transmission and distribution of power are very small. In the single-phase system of the New York, New Haven & Hartford Railroad, between New York City and Stamford, they do not even use raising or lowering transformers in connection with the distribution of electric power, so there are practically no stand-by losses, and the maximum momentary loss between the power-house and the trains at the time of the heaviest power demand probably does not exceed 14.5 percent, and the average loss is less than 4.9 percent of the power-house output.

On the Camden-Atlantic City branch of the Pennsylvania Railroad, where they operate motor-car trains by the direct-current system, the average loss between the power-house and the trains,

including the third-rail losses, is about 33 percent of the power-house output, which is equivalent to saying that the electric power loss in the transmission and distribution system is half as great as the electric power delivered to the trains.

Transmission and Distribution—In most cases the transmission and distribution apparatus is the most costly part of equipping railroads with electric motive power, and it is also the part of the equipment in which there is the greatest difference between the three systems in the cost and efficiency of the apparatus and in the expense of operation.

The construction cost of transmission and distribution apparatus and conductors is in favor of single-phase for nearly all conditions met with in railroading. In general three-phase installations cost 50 to 100 percent more than single-phase; and direct-current installations for handling heavy trains from two to four times more than single-phase.

The operation and maintenance cost of three-phase power distribution apparatus will generally average something like 50 percent more than for single-phase, and for direct current the cost will be several times greater than for single-phase, on account of the rotary converter or motor generator sub-stations.

Locomotive and Motor Car Equipments—Comparison of the motors and other electrical equipment on locomotives and cars for the three electric railroad systems involves the consideration of three essential matters, as well as a vast number of minor details. They are, reliability, economy of construction and efficiency of operation.

Reliability—Excellent reliability has been proven for electric locomotives and motor cars of all three of the recognized electric railroad systems. Mr. A. H. Armstrong, in a paper or discussion before the American Institute of Electrical Engineers, a year or so ago, gave data on the number of locomotive miles averaged by the New York Central direct-current locomotives, per locomotive delay or failure in the electrical zone on the New York terminal. His statement was pretty near to saying that they never had any delays due to motive power failure.

That single-phase railroad apparatus is highly reliable is proven by the successful operation of over forty-five single-phase electric railroad systems in America and Europe. On the single-phase system of the New Haven Railroad, during nine months ending February 28, 1910, the locomotive mileage per locomotive delay from

both mechanical and electrical causes was 12 275 miles. This is two or three times better than steam locomotive average in the same kind of work. For the month of February, on the same system, with over forty electric locomotives in operation, there were only twelve motive power failures, including delays due to the power plant, the transmission and trolley lines and the locomotives, and part of these twelve failures were due to causes that were not electrical, such as derailment, failure of air-brake, etc.

Economy of Construction—Such difference as there is in the cost of electric locomotives for the three systems is chiefly in the cost of the motors and transformers. Single-phase motors cost more than direct-current motors of the same horse-power capacity by something like 20 to 50 percent, and the motors generally make up about one-third, more or less, of the total cost of electric locomotives, the rest being for running gear and other mechanical parts, for control apparatus, etc. Transformers add about three to eight percent to the cost of single-phase locomotives, and a little more to the cost of three-phase locomotives.

Until the manufacture of electric locomotives becomes more general, and standard locomotives of the two kinds are manufactured in considerable quantities, it will not be possible to give the relative cost of direct-current and single-phase locomotives with any degree of exactness; but an addition of between 20 and 50 percent to the cost of the motors, and some increase in their weight as compared with direct-current motors, and the addition of transformers, obviously, will not cause more than 10 to 35 percent increase in the cost of the whole locomotive, and the difference will likely be less than 30 percent.

It is still more difficult to compare the cost of three-phase locomotives with direct-current and single-phase, because, as already explained, three-phase motors will not do as much work, at the variable speeds usually met with in railroading, as will direct-current and single-phase motors of the same continuous horse-power capacity, and while three-phase motors are less costly to build than single-phase motors, and perhaps less costly even than direct-current motors, when rated at their constant speed, they have less advantage in cost, when compared on the basis of equal service capacity at variable speeds, and the cost of three-phase locomotives for ordinary steam railroad work will probably average somewhere between the cost of direct-current and single-phase locomotives.

Efficiency of Operation—The efficiency of operation is not widely different for the three types of locomotives and motor-car equipments used by the three systems. At constant speed and full load, direct-current and three-phase motors are more efficient than single-phase motors by three or four percent, but single-phase motors are more economical for starting and accelerating trains, because other types of motors waste power in resistance when starting. On the other hand, the losses in the transformers used on all single-phase, and on some three-phase locomotives, reduce the average efficiency of the locomotives two or three percent. Also the greater weight of single-phase locomotives and motor cars, compared with those of the other systems, makes more weight to be moved per train, and thus increases the power used, except for freight trains, where the weight is required to get traction.

Including the losses in the transformers on single-phase apparatus, the relative average efficiency of direct-current and single-phase locomotives, doing steam railroad work, varies from about equal efficiency, under some conditions, to as much as six percent in favor of direct current, under other conditions. So much depends on the character of the work to be done, the number of starts and stops to be made, etc., that no close comparison can be made to apply correctly to all conditions. There are even some conditions met with in practice under which single-phase locomotives are more efficient than direct-current locomotives.

It is obvious, from the foregoing, that a vast number of variables, all interdependent and affecting one another, have to be taken into consideration in judging between electric railroad systems.

SUMMARY

Power plants will generally represent about 25 percent of the total cost of electrification and will usually cost about the same for the three systems. The maximum load upon the power plant might not vary greatly for the three systems, but the average load would be greatly in favor of the two alternating-current systems, compared with the direct-current system, on account of the very large losses on the direct-current system between the power-house and the trains.

The conductors and sub-station apparatus for the transmission and distribution of electric power along the tracks is usually the largest item of cost for the electrification of ordinary steam railroads, and is several times greater for the direct-current than for

the single-phase system, and is nearly twice as great for the three-phase as for the single-phase system. The operation and maintenance cost of the sub-stations and transmission and distribution conductors are greatly in favor of both the alternating-current systems, as compared with the direct-current system.

The cost of electric locomotives and electrical equipment on motor cars will generally be somewhere between ten and forty per-cent of the total cost of electrification of steam railroads, and single-phase locomotives will cost somewhat more than direct-current and three-phase locomotives.

Heretofore railroad companies have been deterred from operating heavy trains over long distances by the cost and poor efficiency of the apparatus used to distribute electric power along the tracks. The cost of this apparatus has been greatly reduced and the efficiency greatly improved by modern inventions, so the old limitations no longer apply. With the reliable alternating-current railroad apparatus, which is now available, the economy and other advantages of electric power can be applied to hauling heavy trains long distances, performing the work now being done with steam locomotives, and in many places the increase in net earnings secured will more than pay for the cost of electrical equipment. In other words, it is now often advisable to substitute electric power for steam for purely economical reasons.

CHOKE COILS VERSUS EXTRA INSULATION ON THE END-WINDINGS OF TRANSFORMERS.*

S. M. KINTNER

[This is the fourth of a series of articles dealing with the general subject of continuity of service in trasmission systems, dealing particularly with line stresses and static troubles and the proper protection of transmission systems.]

SURGES along a transmission line are stopped and thrown back by choke coils in a manner analogous to the reflection of water waves by a breakwater at the entrance to a harbor. The quiet of a harbor is obtained by setting up a strong wall capable of withstanding the shock of the waves that strike against it; so is the analogous quiet of a transformer obtained by placing a choke coil in the path of a disturbance. A choke coil will be effective in reflecting and shielding all back of it according to its strength, and its strength is measured by its inductance and insulation. If the former is small, but little reflection will take place, the surge passing through the coil and continuing beyond it. If the insulation of the coil is weak and the inductance is of sufficient value to retard the on-coming wave and throw it back on the line, the rise of voltage may cause a discharge over the coil-face and the wave will continue past the coil. These two conditions can be likened to a breakwater consisting of piling spaced so as to have little effect in retarding an incoming wave in the first instance; and in the second instance, to a breakwater of insufficient height, so that the wave passes over it.

With a given choke coil on a given line, a certain fixed amount of protection will be afforded any apparatus placed back of the coil. There is no relation between the coil and the apparatus being protected that will make the coil more or less effective in its operation of throwing back surges that come in from the line. Tests indicate that a given choke coil affords the same percentage of protection to all parts of the transformer. This was demonstrated by measuring the voltage rises over various parts of the winding of a transformer that was being subjected to static discharges from a condenser, both when the transformer was protected by a choke coil and when unprotected. The protection was taken as the ratio of the reduction in momentary voltage across the windings which resulted from the use of the choke coil to the voltage that existed when it was unprotected. A long series of tests, the results of a

*Revised by the author from a paper read before the American Institute of Electrical Engineers, June, 1907, Niagara Falls, N. Y.

part of which are embodied in a previous article,* have convinced the writer of the truth of the above statements.

In choosing a choke coil for a particular installation, the matter resolves itself into a consideration, first, of the possible surge the apparatus can withstand safely; second, of the probable surge that can be transmitted over the proposed line, the line insulation indicating the maximum voltage that the surge can have during transmission; third, the maximum allowable inductance without seriously affecting the line regulation if an external choke coil is used; fourth, the allowable expense for choke coils as insurance against interruption; fifth, the selection of a choke coil which will most nearly meet the above conditions, the selection being guided by the above, combined with the results of tests and curves similar to those shown in the article referred to.

The question of whether part of the transformer winding should be made strong enough to withstand the surges, and thus have within its own windings a choke coil that protects the rest of the apparatus, or whether an extra coil should be used, is a matter worthy of discussion. The advantages and disadvantages of separate choke coils may be outlined as follows:—

ADVANTAGES OF SEPARATE CHOKE COILS

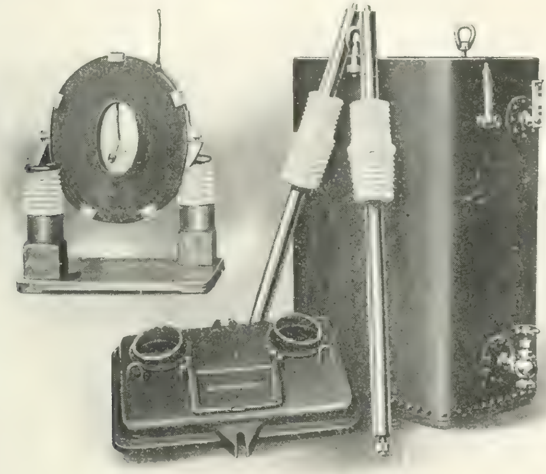
No Voltage Between Turns—One of the greatest advantages of choke coils over extra insulation on the transformer windings lies in the fact that the choke coil does not normally have a voltage between turns. If the insulation of a choke coil fails between turns, nothing in the nature of a short-circuit results, as there is no voltage-difference to maintain an arc. A part of the choke coil will be cut out and will be inoperative, and, consequently, a coil less effective as a whole is the worst that can result. On the other hand, a failure between turns in the insulation of a transformer is vital, and it is almost certain to result in a transformer burn-out.

Uniform Transformer Insulation—If a choke coil is used the transformer may be built with uniform insulation throughout, which is of great advantage to the builder as well as the operator. This permits the safe working of such a transformer with several methods of connection to the line. In the majority of transformer specifications for power transmission the transformer must be capable of operating at one-half voltage at full rated capacity. In general, it is expected also that the transformer may be operated either in

*See "Recent Investigation of Lightning Protective Apparatus," by Mr. R. P. Jackson, in the JOURNAL for August, 1910.

star or delta connection. It is evident that to meet all the above conditions with certain parts of the transformer specially insulated, involves some very complicated insulation arrangements, and necessitates extra insulation on a large part of the whole transformer.

Cheaper Construction—A cheaper transformer may be used safely with a choke coil. In considering the cost of transformers, it should be remembered that the better grade of transformers of 1 000 kw and upward for power transmission are wound with copper ribbon, one turn per layer. These coils are insulated uniformly throughout so as to stand momentary voltages of from 5 000



OIL INSULATED CHOKE COIL
Single-pole, 33 000 volts, 10 amperes.

to 9 000 volts between turns. In order to get this result, only about eight to ten percent of the available winding space can be used for copper, the rest being given up to solid insulation and oil-ventilating ducts. An increase in insulation over the above is not desirable with the insulating materials in use at the present time for two reasons: First, the coils cannot be made strong enough mechanically to stay in place under the shocks to which they are subjected; second, the extra insulation retains the heat from the copper, and thus is more liable to be burned out and necessitates a much lower rating of the transformer. Moreover, it is difficult for workmen to handle large coils with extra heavy insulation without injury to the

insulation. It is, therefore, evident that the method of using extra insulation involves a much more expensive transformer and one that is more liable to damage in handling.

Choke Coil Easier to Insulate—A choke coil can be insulated much more strongly than a transformer, due to the fact that more material can be used between turns, and it can be disposed to better advantage by allowing more extension beyond the copper than can be employed economically in a transformer coil; also the shape of the coil is much simpler than that of the average transformer coil, and thus more readily insulated.

DISADVANTAGES OF CHOKE COILS

More Apparatus—One of the disadvantages of the choke coil over the use of extra insulation on the transformer is the increase in the number of pieces of apparatus, but this is very materially reduced when it is permissible to mount the choke coils inside of the transformer tank. It is thus possible to make the choke coil a part of the transformer terminal, the coil being connected in series between a line (end) connection of the transformer and one of the high-tension terminals.

Complicates Station Wiring—Another disadvantage of the separate choke coil is that its use complicates the wiring. For some installations it is possible to use choke coils mounted in the air and made a part of the station wiring, but in general the oil-insulated coil is to be preferred. Past practice has been to have each oil-insulated choke coil mounted in its own tank, but there seems to be no good reason why they cannot be placed inside the transformer tank, thereby saving considerable floor space as well as outside wiring.

After a thorough consideration of the above points, it is the writer's opinion that, for a given expenditure to provide protection against surges, better results can be obtained by the use of choke coils in connection with a transformer of reasonable insulation than can be secured by the use of transformers with special heavy insulation on parts of the winding and without choke coils.

THE DETERMINATION OF PULLEY AND BELT SIZES

C. B. MILLS

THE determination of the proper sizes of pulleys and belts for motors or generators and their relative proportions and speeds is frequently one of the difficult features of an installation. This is largely due to the lack of usable information bearing on the question at hand. It is comparatively easy to determine such relative sizes and speeds as will result in a given speed ratio; but to determine which particular sizes will give the desired speed ratio with best efficiency and with no excessive strains at any point, requires more careful analysis. Considering the belting and pulleys as separate from the motor, no different treatment is required than for an ordinary drive between line-shafts, excepting that for motors the belt speeds are usually higher and, therefore, on account of increased centrifugal stresses in the belt fabric, the effective power transmitting stresses necessarily have to be lower to avoid overstraining or breaking the belt

Good oak-tanned leather belting has a net tensile strength of approximately 4 000 pounds per square inch of cross-section. Using a factor of safety of ten, a fair allowance considering the effect of joints, etc., would give for single or light double belts on iron pulleys a permissible driving tension of from 40 to 50 pounds per inch width, the heavier strains not to be used with belt speeds of over 4 000 feet per minute. Belt speeds over 5 500 feet per minute should not be considered except for very special conditions. With heavy double belts on iron pulleys, these figures for loading may be increased to from 60 to 80 pounds per inch width with the same limitations on higher speeds as for light double belts. Under the same conditions as given above the driving tensions in belts running on paper pulleys can be increased approximately 30 percent over the figures given, as, owing to the higher coefficient of friction on paper, the initial tensions required to prevent slipping are much reduced.

A measurement of the transmitting capacity of belting is frequently expressed as the "number of feet of one inch wide belt per minute per horse-power." For single or light double belt this expression is usually given a value of about 700, and for heavy

double belt approximately 450. These values are equal to 58 square feet of belt per minute per horse-power for single or light double belt and 38 square feet per minute for heavy double belt, and correspond closely to the strain values given above.

In considering a specific case, attention should be paid to the arc of belt contact on the smaller pulley, as decrease of lap and consequent decrease of friction contact means higher belt stresses due to the greater tension required to prevent slipping. The percentage increase of belt per minute required to prevent slipping with a contact angle of less than 180 degrees is shown in Table I. The arc of contact is best determined graphically for any particular application.

TABLE I.

Arc of Contact Degrees	170	160	150	140	130	120	110	100	90
Increase in Belt per min. Percent.	3	6	9	13	17	21	25	30	35

The accompanying chart furnishes an easy graphic solution of belt problems within the range of ordinary industrial conditions, and is based on the data given above.

It should be noted from the horse-power curves that for speeds exceeding 5 000 feet per minute, an increase in speed does not produce a proportionate increase in horse-power transmitted, on account of the centrifugal force of the belt. At speeds above 6 000 to 6 500 feet per minute the horse-power transmitted must be actually decreased in order not to exceed the assumed maximum permissible stress.

In using the chart, knowing the size of pulley and revolutions per minute, the feet per minute belt travel will be represented by the vertical line at the intersection of the corresponding horizontal and diagonal lines, interpolating if necessary. From this value, the diameter of the other pulley at any given speed can be readily determined. Knowing the feet per minute, the horse-power that can be transmitted per inch width of a given size belt for a contact angle of 180 degrees on the smaller pulley of the pair can be read directly from the curves at the top of the diagram. For contact angles smaller than 180 degrees, or, as when using belt tighteners, etc., for larger angles, a correction must be made by means of the diagonal lines at the center of the chart. From the intersection of the vertical line representing the

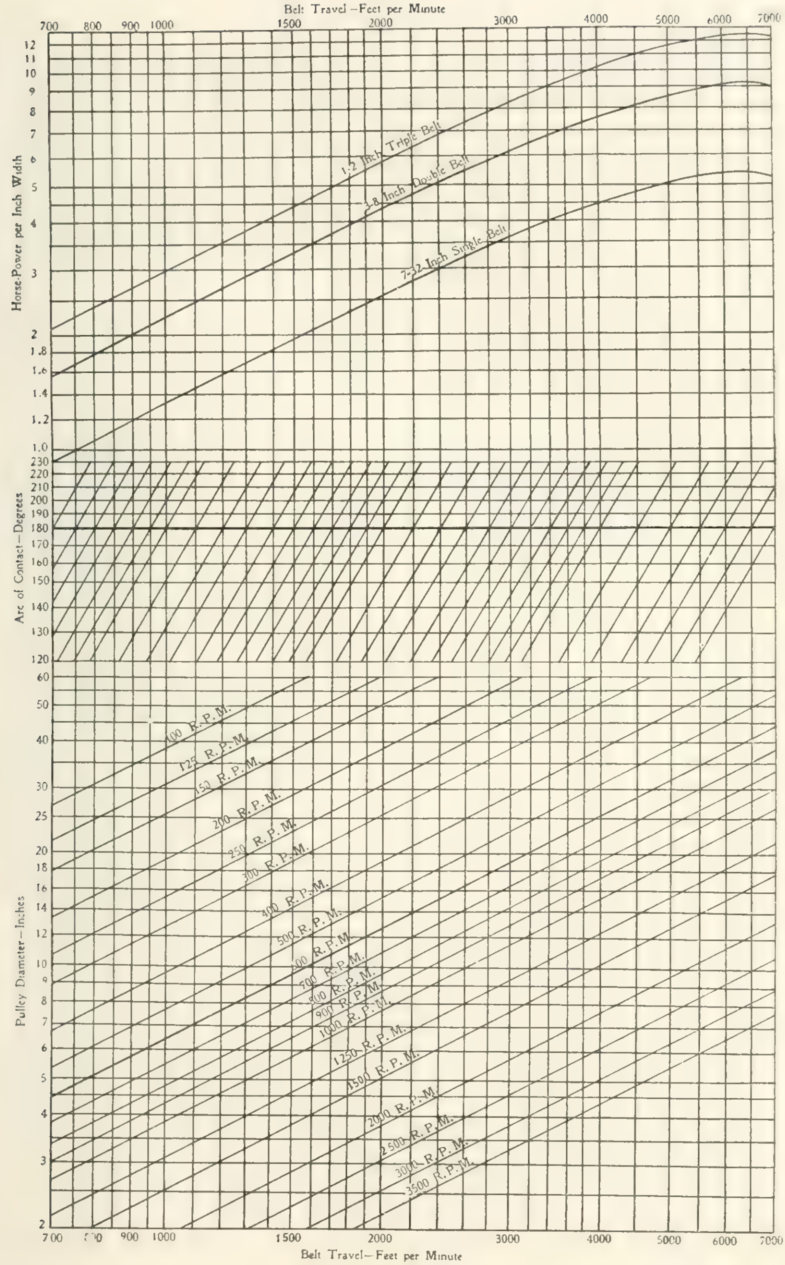


CHART FOR CALCULATING BELT HORSE-POWER

Values given for leather beltson iron pulleys. Maximum permissible stress, 400 lbs. per sq. in. Forpaper pulleys, add 30 percent to horse-power values on chart. Forfour-ply canvas or rubber belts use curve for single leather belts.

given belt speed and the horizontal corresponding to 180 degrees contact, follow the diagonal to the horizontal line corresponding to the desired angle of contact. The vertical passing through this intersection gives a corrected belt speed, i. e., that speed which at an angle of 180 degrees will transmit the same horse-power as the given speed at the given contact angle. The horse-power per inch width of any thickness belt can then be read direct from this corrected speed.

Example I—What width of single belt will be required to transmit 15 horse-power over a nine inch pulley at 1 000 r.p.m., with an arc of contact of 160 degrees?

Reading from the nine inch line to the 1 000 r.p.m. diagonal gives 2 360 feet per minute belt travel. From the intersection of this interpolated line with the 180 degree line, follow the diagonal to the 160 degree horizontal line. This gives a corrected equivalent belt speed of 2 200 feet per minute. The intersection of this line with the curves for single belts shows a value of 2.8 horse-power per inch width. To transmit 15 horse-power will, therefore, require a 5.5. inch belt.

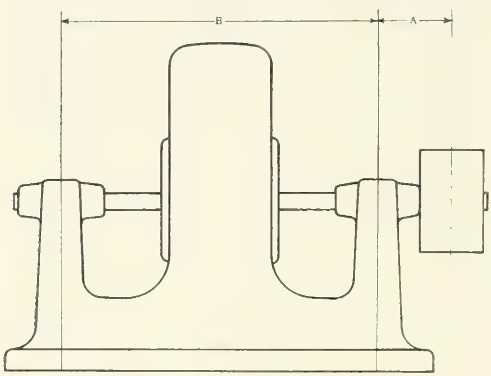


FIG. 1

Example II—How much power can be transmitted by a 15 inch double belt over a 40 inch pulley at 250 r.p.m. with an arc of contact of 210 degrees, secured by the use of an idle pulley?

Reading from the 40 inch line to 250 r.p.m. gives a belt travel of 2 600 feet per minute. From the intersection of this line with the 180 degree line, follow the diagonal to the 210 degree line. This gives an equivalent speed of 2 800 feet per minute. The intersection of this line with the curve for double belting shows a value of 5.8 horse-power per inch width. A 15 inch belt will, therefore, transmit 87 horse-power.

The chart may also be used for solving other types of problems besides those given in the above examples.

SHAFT STRESSES

The necessary initial tension required in each side of a belt in order to transmit a certain pull without slipping has been found from practice to be about equal to the effective pull on the driving side for cast iron pulleys and for paper pulleys at least equal to one half the driving tension. The resultant load *R*, therefore, on a shaft carrying a cast iron pulley would be the initial tension plus driving tension or, $R = 3\frac{hp \times 33\,000}{\text{Belt speed}}$, and for a paper pulley, $R = 2\,\frac{hp \times 33\,000}{\text{Belt speed}}$

The action of this loading is to set up bending and twisting strains in the shaft material, and these working stresses must necessarily be considerably below the elastic limit of the material in order to prevent bending or fracturing of the shaft. In calculating stresses in a shaft due to transmitting power over a pulley of a certain size it is convenient to figure the bending moments and twisting moments separately and then resolve the two moments into an equivalent twisting moment, using the polar section modulus for finding stresses.

For an overhung pulley, the bending moment $= M_B = L\,D$, in which L = resultant load in pounds on the pulley and D = the distance in inches from the center line of the pulley to the center line of the bearing.

The twisting moment due to driving force $= M_T = R\,P$, in which R = the radius of the pulley in inches, and P = the effective transmitting pull on the belt.

The equivalent twisting moment combining these two moments will be given by the following equation:

$$M_{T_1} = M_B + \sqrt{M_B^2 + M_T^2}$$

As shafting is ordinarily of circular section the property to resist torsion is expressed as the polar section modulus and for a round shaft is as follows,—$P.\,S.\,M. = \frac{\pi d^3}{16}$; in which d = diameter of shaft in inches. The actual stresses S in a shaft, in pounds per square inch, will therefore be $S = \frac{M_{T_1}}{P.\,S.\,M.}$ = maximum stress per square inch.

For ordinary soft steel shafting or cold rolled stock, the value given by the above equation should not exceed approxi-

mately 6 000 which will give a factor of safety of about five, while for the higher grades of high carbon steel shafting this figure may be safely increased to from 8 000 to 10 000 without danger.

The effect of different sizes of pulleys on motor bearings should also be considered, as it will be evident that, as the belt tension becomes greater with a decrease in pulley diameter, the bearing pressures will be correspondingly increased and will rapidly reach the danger limit. The total resultant load on the shaft at the pulley being known (see calculation for shaft stress) the reaction on the bearing nearest to the pulley will be given by the following equation (see Fig. 1):

Reaction $= \frac{P(A+B)}{B}$ in which $P =$ total resultant on pulley, $A =$ distance from center line of pulley to center line of bearing, $B =$ the distance between center lines of bearings.

The total reaction on the bearing in pounds divided by the projected area of the bearing will give the bearing pressure in pounds per square inch. Bearing pressure may then be expressed as follows:

$$B\ P = \frac{\text{total reaction in lbs.}}{\text{dia.} \times \text{length of bearing}}$$

Where the dead weight on the bearing due to pulley and belt is considerable, these factors should be taken into consideration when estimating bearing pressures. In any well designed bearing, the bearing pressure may vary over a considerable range with perfectly satisfactory operation. It is a better and safer practice, however, to limit the pressure due to dead weight and pulley action so as not to exceed 60 to 70 pounds per square inch projected area on motors under 50 horse-power, as the inherently small outer radiating surface of such bearings is not able to radiate the heat generated under the heavier pressures, and dangerous temperatures are easily reached. On large machines, bearing pressures of 80 to 125 pounds may be used if the bearings are well designed and operate under favorable local conditions.

It will be apparent from the foregoing that the limitations imposed by the bearings of a motor are the principal factors in determining the smallest pulleys which may be used, good practice allowing a smaller margin of safety in these parts than in others, owing to their ability to give evidence of distress by heating, long before the danger line is reached.

EXPERIENCE ON THE ROAD

PREVENTION OF SYPHONING OF TRANSFORMER OIL

J. C. DOW

OIL may be siphoned out of a transformer case by the leads in two ways—by the insulation, or by the capillary action of the oil in the spaces between the wires of the flexible leads. To prevent the former all that it necessary is to remove the insulation for an inch or two above the oil surface within the case. To prevent the second action the spaces between the wires must be filled with some oil repellant. This can be accomplished by using a solid lead or by filling the flexible lead with solder, but neither method prevents the oil from creeping along the surface and both require the lead to be non-flexible at least for part of its length.

It is possible, however, to fill a short section of the cable above the oil in the case with glycerine, thus preventing the oil from syphoning and still leaving the cable flexible. The cable must first be stripped of its insulation for two or three inches or more, depending on its size, the oil thoroughly removed from that section of the cable and pure glycerine run in. The oil can be removed with gasoline and this must be done thoroughly all through that section of the cable. The slight residue left from the evaporation of the gasoline will prevent the glycerine from working into the cable, but this residue can be removed with alcohol. This removal must also be thorough. The alcohol should then be removed before drying by means of water, and while the cable is still wet, the glycerine is worked in. The glycerine should be as pure as possible, but it may be necessary at first to use a solution of glycerine in water to make it enter the cable. Glycerine is an oil repellant, but is an absorber of moisture, and hence this method should be used with caution on high-voltage transformers.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

478—Protection of Circuits Against Surges and Lightning Disturbances—An installation of transformers is operated in connection with a 13 000 volt, 60 cycle, three-phase distribution system, supposed to be properly equipped with lightning arresters. Rises of voltage have occurred, causing burn-outs in a number of transformers. Needle-point spark gaps have been connected across the terminals of several transformers and, when they were set with a gap of one and seven-eighth inch, discharges have been observed. May not such rises of voltage be regarded as indicating abnormal conditions or may rises of two or three times normal voltage be anticipated on such a system?

F. M. D.

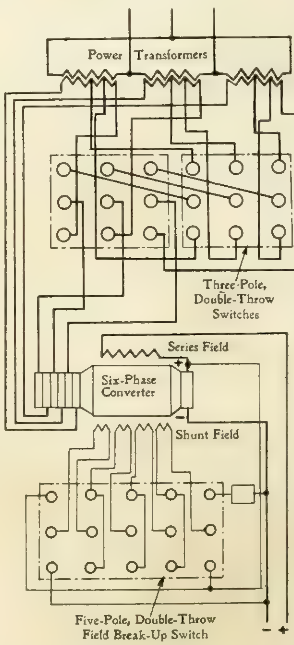
A discharge will take place across a one and seven-eighth inch gap with a rise of voltage to about 30 000 to 35 000 volts. This is abnormal on a 13 000 volt system. Suitable arresters located at the points where these rises take place should discharge and thus prevent such occurrences. Normally, rises of 35 percent are about as high as should occur in switching, and the arresters should discharge at voltages but little above this value.

R. P. J.

479—Operation of Self-Starting Synchronous Converter with Field Break-Up Switch—What takes place in a self-starting synchronous converter when the field break-up switch is thrown from one position to the other? Also, why is the rheostat connected so as to be in circuit on one throw only?

A. L. H.

It is customary, in connection with self-starting synchronous converters, to provide a combined field break-up and reversing switch, mounted on the frame of the machine. This switch is connected in the field circuit in such a manner as to open the circuit at several points when thrown open during starting, thus preventing



NO. 479 (a)

an accumulation of the voltage induced in the field by the alternating-current applied to the armature. When the alternating-current circuit is connected to the armature of a self-starting synchronous converter, the polarity on the direct-current side of the converter is not fixed, i. e., it may build up "right" or "reversed."

At the moment the machine is connected to the alternating-current circuit, the field break-up and reversing switch is open, there is no current flowing in the field coils and the converter starts as an ordinary induction motor. At first, the needle of the voltmeter connected across the direct-current terminals will swing back and forth and it will only begin to point steadily in one direction after the speed has nearly reached the synchronous value. In case the polarity happens to be the one desired, the field switch is closed. After this is done, the direct-current voltage will continue to build up and the full alternating-current line voltage can be applied. In case the direct-current voltage builds up reversed, the field switch is thrown in what is termed the "reversed" position. In this case the current flowing through the field coils causes the field flux to oppose the armature flux, the direction of the latter being fixed by the alternating-current. As is well known, the rotating field set up by the alternating-current results in a flux which is stationary with respect to the field poles, when the armature is running at synchronous speed, the same as the flux introduced by the field coils. Hence, the conditions explained above mean that the two resulting fluxes are opposing one another. This condition can only result in either the armature flux overcoming the field flux or vice-versa. If the armature flux remain the stronger, the converter will continue to operate with reversed polarity and under very unstable conditions. If the field flux becomes the stronger it will tend to destroy the armature flux and the result will be that it will push the armature flux aside, i. e., out into the space between the poles, whereupon it will be displaced until it coincides with the field flux of the respective adjacent poles. This action is designated by stating that the converter "slips a pole." When the armature flux is being pushed over from one pole to another the direct-current voltage passes from a certain value at one polarity through zero and then begins to build up with reversed polarity. Simultaneously, the field current passes through the same cycle and, therefore, at the moment that the direct-current voltage starts to build up in the opposite direction, the field switch will have to be thrown over so as to prevent the field flux from again building up in a reversed direction relative to the armature flux. It is, therefore, because of this reversal of the field flux, caused by the reversal of the armature flux, that the field switch is to be thrown over at the instant the converter slips a pole. The field rheostat is not connected in the circuit when the field switch is thrown in the reverse position, inasmuch as this position does not correspond to a normal operating condition, but is used for starting only, and moreover because it is necessary to get the greatest current possible through the field coils, in order that the desired reversal and slipping of a pole shall take place. A method of connecting the alternating-current circuit of the armature to the transformers arranged for six-phase operation and self-starting by means of two double-throw switches, and connections of the shunt fields to the field break-up switch, are shown in Fig. 479 (a).

J. B-W.

480—Electrolytic Action on Brushes—In the answer to No. 336 in the Dec., 1909, issue of the JOURNAL, the statement is made that the "commutator is positive to the negative brush." The answer further describes the action as electrolytic. Will you kindly explain the meaning of this part of the answer? Further, if an ordinary voltmeter test is made will not the negative brush show positive to the commutator? With the commutator negative to the brush, if a spark is formed, the commutator bar becomes the negative electrode of an electric arc, and furnishes the material for the arc stream.

C. W. K.

The answer as printed is cor-

rect in regard to the relative potential of the commutator and negative brush. The current flows out from the commutator via the negative brush in the case of a direct-current *motor* and if a voltmeter test is made, the commutator will show positive to the negative brush. With a direct-current *generator* the reverse will be the case and the blackening will be under the positive brush if under either. The action which takes place is called electrolytic for want of a better name, and is understood to mean that a chemical and physical change is produced by the flow of electric current between the two substances, not necessarily with any visible arc. L. W. C.

481—Determination of Field Current of Synchronous Motor at Unity Power-Factor—In connection with a synchronous motor already installed it is desired to determine the value of field current required to give unity power-factor at a given load. How may this be done? R. A. G.

To operate a synchronous motor at unity power-factor the field current must be that at which the line current for a given load is a minimum. With the machine in operation this field current may be found by trial and adjusted for different loads, or it may be predetermined for any given load from no-load saturation and short-circuit tests taken from the motor when driven as a generator. To carry on these tests the following are required: A means of driving the machine as a generator; a main circuit ammeter and voltmeter; a field ammeter; and a low reading voltmeter for obtaining the resistance of the armature circuits. First, the resistance of the armature circuit is measured by the ammeter-voltmeter method, taking the average of several readings, from which data the IR drop at the load in question may be calculated. The machine is then driven at synchronous speed as a generator. Sufficient field current is then applied to give normal voltage. To this normal voltage add the armature drop as determined above and increase the field current until this potential is indicated on the main voltmeter; note also the corresponding current on the field ammeter. Next, determine the field current required to circulate normal amperes per terminal for the load in question through the armature windings when short-circuited. For three-phase machines connect the three phases together and for two-phase machines short-circuit each phase separately. The exciting current at unity power-factor will then be equal to the square root of the sum of the squares of this short-circuit field current and the field amperes required to give the full voltage at no load plus the IR drop in the armature as previously outlined. These tests were described in detail in articles on "Factory Testing," by R. E. Workman, under the subject of "Regulation of Alternators," in the JOURNAL for Dec., 1904, and Jan., 1905. See also pp. 115-117 in the JOURNAL for Feb., 1905, in which is outlined the method of determining by trial the values of field current which will give unity power-factor on a machine at various loads. S. N. C.

482—Reading Course on Illuminating Engineering—Please advise proper course of reading to give one a sufficiently thorough general understanding of the theory and practice of illuminating engineering. What is desired is not reference to an exhaustive study of this subject, so much as to the briefest course of careful reading which will give one a sufficiently trustworthy general knowledge of the subject to permit him to advise and handle the simpler sort of illumination problems. C. V. A.

The best literature with which to begin a brief study course in illuminating engineering is Cravath & Lansingh's "Practical Illumination." This book takes up, in a very brief yet complete way, the essential principles of the subject, then deals with the various types of illuminants and the results given by them, and finally takes up the different types of

lighting problems, as residence lighting, office lighting, public room lighting, etc., and shows the general way in which each class of illumination problem should be treated. The book is admirably and extensively illustrated and is particularly written for the man who desires to obtain a working knowledge of the subject rather than for the student who is interested primarily in the more abstruse questions of theory. After "Practical Illumination," Dr. Louis Bell's "The Art of Illumination" can be very profitably read. The above two books will give one enough of the theory of the subject for a satisfactory working knowledge. As illuminating engineering is decidedly a science which is in progress of active development, the man who expects to practice it as a profession, even on a very modest scale, should keep in closest touch with the latest developments of the science, especially in matters directly concerning practice. The best way to do this is to join the Illuminating Engineering Society, if only in order to obtain the Transactions of this society. The work of the society has been of a very high order, and the yearly dues of $5.00 are an insignificant price to pay for the very valuable literature covered by the Transactions. The articles on illumination which have been published from time to time in the JOURNAL (see Six-Year Topical Index) may also be referred to with profit. Many of the commercial companies are publishing literature dealing with the use of their products along lines of correct illuminating engineering practice. The various incandescent lamp companies and the Holophane Company, have published in their bulletins considerable valuable information. Any of this can be obtained gratis by addressing requests to the proper parties, as follows: National Electric Lamp Association, Cleveland, O.; Westinghouse Lamp Company, Bloomfield, N. J.; General Electric Company, Harrison, N. J.; Holophane Company, Newark, Ohio.

A. J. S.

483—Oil Testing Apparatus—Referring to article on "Transformer Oil" in the JOURNAL for May, 1904, particularly the oil testing apparatus; and question No. 437, I note the depth of the lower terminal in the oil is not given. With a similar apparatus having a glass cylinder of one and one-half inch inside diameter, using one-half inch balls and one-fourth inch rods, and having the lower terminal point always immersed the same distance, say, seven inches in the oil, *a*—What should be the standard gap? *b*—What is the gap at which the oil will break at no less than 30 000 volts, 50 cycles? *c*—How does a 0.2 inch gap compare? *d*—What injury can plaster of paris do as a filler at the base of the bottom terminal? *e*—Are there any curves or methods of computing a curve to give relative voltage break-down value corresponding to various gaps for a seven inch depth or vice-versa?

L. J. T.

a—Any convenient gap may be taken as standard for any given set of tests. However, it is found convenient to use a constant standard gap such as 0.015 inch (Westinghouse) or 0.2 inch (General Electric) for all work. *b*—Well dried oil should not break at less than 30 000 volts, 60 cycles, on a gap of 0.15 inch, or 40 000 volts on a 0.2 inch gap. The oil must, however, be in first class condition to stand this test. *c*—Tests that have been made with 0.15 inch gaps have shown a break-down almost exactly in proportion to the size of the gap. *d*—Plaster paris, well dried out, will not cause any difficulty at the bottom terminal, but it must be remembered that plaster paris very readily takes up water and, if it becomes saturated, it might give up some moisture to the oil under test, and therefore vitiate the test. *e*—We do not know of any such curves, or methods for computing them. Oil tests, as a rule, are inclined to be very erratic, and for satisfactory comparisons the selection of a standard gap, a standard terminal, a standard depth beneath

the surface, etc., will eliminate much of the difficulty which would otherwise be experienced in attempting comparisons between different oils. It is difficult to make comparisons between tests made by different observers, on account of the fact that there is usually some variation in method, apparatus, etc. See No. 372. C. E. S.

484—Maintenance of Railway Motor Bearings—What is the best method to follow in connection with the maintenance of railway motor bearings, both armature and auxiliary bearings? What allowance should be made for clearance in order to take care of oil space and unavoidable irregularities? Should the bearings be scraped separately, using a standard sized plug about 0.002 inch larger in diameter than the journal? This method would not seem to insure proper alignment. It is, of course, bad practice to renew one bearing without renewing the other also. Is a soft metal lining advisable in the case of a split bearing? Does heating ever occur from tightening the set screws too tight? It is proposed to make the bearings in quantity in the shop and place them in stock for use as needed for repairs. G. F. S.

A set of bearings should be clamped in a carefully made jig chuck after casting, and bored to the following allowances: Solid bearings, 0.002 inch per inch diameter of bearing; split bearings, 0.003 inch per inch diameter of bearing. It should not be necessary to test for alignment in the motor frame if the proper tools are used. A tin base metal is considered the most economical, all factors being taken into account. The practice is sometimes followed of supplying a stock of bearings standardized to, say, three sizes differing slightly in diameter. The larger size of bearing is used for new equipment, the second size for equipments in which the journals have worn sufficiently to require repair, whereupon the latter are turned down to a size corresponding with the second standard size of bearing; the next smaller size of bearing is used in a similar way for equipments requiring a third renewal, etc. The economy of a given method of maintenance depends on the number of equipments of a given type that are involved and also upon the total number of equipments in operation. J. E. W.

485—Steam vs. Electric Operation of Steel Roll Mill—Will you kindly give me the comparative cost of operation and efficiency between the ordinary engine and electric motor for steel roll mill drives? Also, considering that the turbo-generator which supplies the motor is so arranged that it will always have very near full-load, due to the fact that its load includes other drives, what would be the comparison between the roll engine and a turbo-generator and motor considered as a unit; labor and oil not considered on a turbo-generator, and steam for both turbo-generator and roll engine assumed to be derived from the same source. N. J.

The relative advantages of the two methods of drive for a given case depend entirely on the specific conditions of operation involved. It may be stated in general that the question of application of electric motors vs. steam engine drive from the standpoint of economy of operation depends on whether cheap power is available. Numerous cases may be cited where, because of high cost of fuel, the saving in operating expenses effected by the employment of gas engine driven generators or exhaust steam turbine units is such as to warrant the investment of considerable capital in such equipments for the purpose of applying motor drive. In many cases the possibility of obtaining desirable operating characteristics through the use of motor drive has an important bearing on the question, as the flexibility of design possible with the types of motors applicable to such work gives much greater latitude in adapting their characteristics to the requirements of specific cases than is possible with direct steam engine drive.

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Power Operated Car Control Apparatus

Much of the progress of the present century has been due to the substitution of mechanical power for manual labor wherever possible. Power operated brakes for electric cars have long since superceded hand brakes, except for cars of the smallest size, and a similar adoption of power operated control apparatus in place of the usual manually operated drum type controllers, is only a matter of time. As pointed out by Mr. Simmon, in his article on "Hand Operated Multiple-Unit Control," in this issue of the JOURNAL, such control apparatus offers many advantages. It is already generally employed for large equipments and the simplicity of the outfits which he describes will undoubtedly do much to hasten its more frequent application to smaller sizes.

Improvements made for the purpose of accomplishing one result often introduce others incidentally. In the adoption of power brakes for cars operating in city service, it was found that the power consumption was considerably reduced. This was due to the fact that on account of the better control of the brakes the motormen no longer followed the wasteful practice of running with the brakes partly set, but released them fully after every application, knowing that they could readily be applied again, if needed, with no particular physical exertion. In addition to the advantages mentioned by Mr. Simmon it is not unlikely that the application of power operated control apparatus to service in which frequent stops are made may produce a similar saving on account of the greater physical ease with which the application of the current can be governed.

As an instance of the great flexibility of the elements of the unit switch control system it may be mentioned that the essential parts of the multiple-unit control equipments for the single-phase cars described by Mr. Riley in this issue are exactly the same as those described by Mr. Simmon for use with direct-current equip-

ments. Aside from the fact that the main and control circuit connections are different on account of the entirely different schemes of control used in the two cases, the pneumatically operated switch groups differ only in the fact that a small storage battery is employed for operating the magnet valves in the latter case instead of a branch circuit from the trolley.

The use of multiple-unit control for single-phase car equipments offers even more advantages than in the case of direct-current trolley cars, since on account of the extremely small line drop longer trains can be operated. A remarkable instance of the results which can be accomplished was shown during the past summer on the single-phase line of the Chicago, Lake Shore & South Bend Railway, on which an eleven car multiple-unit picnic train, made up of six 500 horse-power motor cars and five trailers was operated for a distance of nearly sixty miles. Such a train would have been utterly impossible on any direct-current interurban trolley road, and in the present case the record which it established stands as a remarkable testimonial to the advantages of unit switch control and the single-phase railway system.

Clarence Renshaw

Reduction in the Cost of Railway Equipment Maintenance

It has been said that "Necessity is the mother of invention," and this may be the cause of some of the improvements in methods of railway equipment maintenance which have occurred in the past several years. The numerous restrictions and burdens imposed by some of the State Commissions have made it necessary for managements to increase or maintain their earnings largely by reducing maintenance costs. In the great majority of cases the master mechanics or superintendents have, so to speak, rolled up their sleeves, grappled with the problem and ultimately secured the desired result. Many of the records show material reduction in maintenance costs each year over those of previous years, notwithstanding the fact that labor and material have increased in cost.

Material assistance has been secured by operators through discussions engaged in at the various railway clubs and conventions, as well as from published articles dealing with this problem. Many of the leading operating men realized very early that their maintenance costs were excessive, and that it would be more economical to discontinue the use of some of their standard apparatus and

adopt improved ideas. The manufacturers of railway appliances have also contributed their share in this march of progress, in developing designs of units or parts which would enable the operating man to reduce the costs of upkeep. This effort and study of many intelligent operating men and designers resulted in the discovery that thousands of dollars have been wasted in both the hauling and maintenance of unnecessary weight, and this in turn has caused a demand for further changes and improvements in design and manufacture of railway apparatus.

Possibly the greatest factor in the results secured has been the scientific study and solution of the problem of "upkeep," or, in other words, an exact knowledge of the daily attention required by each part of the equipment, as indicated by periodic inspection and overhauling. These records disclosed the fact that some parts of the equipment required more frequent renovation than others, and it was in many cases annoying to find, for instance, that armature bearings had to be renewed every four or five months, while the balance of the motor could run for much longer periods, and that certain few parts required more frequent inspections than the remainder of the equipment. It was this condition which unquestionably gave birth to the demand for improvement of various parts, and the result is that the modern railway motor may be continued in service several times longer between overhauling or inspection periods than the older types, with entire safety and with proportionate economy in maintenance.

It may be of interest to mention here some of the features in which improvements have been most marked.

Armature bearings may now be had with an average life of 200 000 miles, which will run without attention or replenishing of oil for a month or longer, and are so constructed that waste of oil is negligible.

Commutators, with the mica undercut, used in conjunction with modern carbons and adjustable spring tension have had their periods of usefulness multiplied many times. Troubles brought on through accumulation of carbon and copper dust inside the motors have also been reduced to a minimum. In addition, by the use of interpole construction, sparking has been practically eliminated, with still greater decrease in wear of commutators and brushes.

Brush holders with protected mica insulation and substantial stud bolt construction have been made so reliable that frequent inspection of these parts is unnecessary.

Field coils are now made of strap wound copper, insulated with asbestos and impregnated with high grade insulating compounds. They are provided with metal shields and cushion springs to eliminate the mechanical difficulties which were common with former types. They require no inspection, merely repainting at overhauling periods.

The use of armatures with special reinforced insulation at the ends of core slots, with asbestos hoods and other improvements, has more than trebled the interval between repairs; while the use of improved spider construction has made it possible to replace a damaged shaft without disturbing the winding or commutator.

Gear cases are of more substantial construction than formerly and are provided with safety clamps which prevent the lower half from dropping, even if the suspension bolt nuts work off.

The box frame construction is a more compact form of construction and is free from the necessity for clamping bolts, but, inasmuch as the split frame has many advantages, this type has been brought up to modern requirements and is so constructed as to be equally reliable.

Multiple-unit control equipments have been much improved. A light weight form of this type of control has been developed and is now extensively used, which is much more reliable than the platform control, and has the great advantage of removing from the car platforms all power wiring and heavy current-carrying parts, and absolutely eliminating injury to passengers or employes due to controller or circuit breaker explosions.

The car bodies, trucks, wheels, brakes, trolleys and other details have also kept pace with this march of progress, so that the entire car equipment requires much less expense for inspection and maintenance than was formerly thought unavoidable.

M. B. Lambert

Terminals for High Voltage Service

Until the advent of the condenser type terminal, described by Mr. Reynders, in this issue of the Journal, the problem of designing an adequate terminal for electrical purposes was in many respects similar to the problem of designing guns. It is well known that the strength of a gun is not in proportion to the thickness of the tube which forms the barrel. It is also well known that, after the tube

has reached a given thickness, additional metal is practically useless, since under the stress of the explosion the strains on those portions of the tube wall next to the bore are greater than on those at the outside of the barrel in approximately inverse proportion to the diameters. Under these conditions the only way to make stronger guns is to use stronger material for the walls of the gun.

Electrical terminals of the older type were subject to very similar limitations. That portion of the dielectric next to the conductor was under a higher unit strain than the portions further away, the electrical strains being in approximately inverse proportion to the diameters. But the development of the new type of terminal has changed all this. It was just as if someone had found a method of adding metal indefinitely to the wall of a gun tube in such a manner that the metal on the outside would be strained to the same point, and would do exactly the same amount of good as the same thickness of metal next to the bore.

The condenser type terminal marks an epoch in electrical development. It removes completely a difficulty which was found particularly acute in the design and manufacture of high-tension transformers and switches, and which, for a time, actually threatened to form a limit to an increase in transmission voltages. The necessities of high insulation, effective cooling and the smothering of arcs make it absolutely essential that both high-tension transformers and high-tension switches be immersed in a bath of oil. The high voltages and large capacities of modern electrical plants further make necessary the use of such oil in large quantities. Considerations of fire risk, the possibility of igniting the vapors above the oil and the development of a pressure within the tanks due to the opening of arcs, etc., have made it necessary to place the oil in strong, all-metal tanks, preferably of steel. We are, therefore, logically led to the necessity of taking currents at 100 000 volts or more into the interior of such steel tanks. Moreover, the terminals we insert in the walls of these tanks must meet a number of obvious requirements. They must be so strong electrically that, if any part of the system in which they are used breaks down, it shall be some part other than the terminals. They must be sufficiently strong mechanically to successfully withstand any pressures that may be developed within the tanks by vapor explosions, etc. They must not require the cutting out of apertures in the metal tank covers of such a size as to weaken them. They must be ca-

pable of hermetic sealing, as the terminals are sometimes used for outdoor service. The possibility of admitting moisture into transformers makes this point essential.

All of these requirements are beautifully met by the terminal described by Mr. Reynders. No longer is it possible that considerations of terminals shall limit voltages. The limitations of increase in transmission voltages must come from some other feature than the necessity of taking such voltages into and out of steel or other metallic containers. This is a difficult problem well solved.

P. M. Lincoln

Railway Electrification in Europe

"What did you see in railway electrification in Europe?" has been asked and answered several times since my recent trip abroad.

My time was short; I did not see everything, and my story is incomplete; but what I did observe interested me, and may interest others as well.

At the Simplon tunnel the trains are handled very smoothly by the Brown-Boveri three-phase locomotives. They run about forty miles per hour through the single-track tunnel, thirteen miles long with an up-grade each way to the middle. The overhead construction is simple, and in the yards outside of the tunnel the support is a light frame work of two-inch gas-pipe. Clean and agreeable as is the tunnel compared with others where steam locomotion is used, yet it is a poor substitute on a pleasant day for the beautiful trip over the Simplon Pass by the road built by Napoleon a century ago. This route, however, takes from seven o'clock in the morning until four in the afternoon instead of twenty minutes by the electric trains.

It is in sunny Italy, however, that the three-phase system flourishes best. The success of the Valtellina line of the Italian State Railways during the past eight years has led to the adoption of three-phase locomotives for the program now being carried out in the vicinity of Genoa. A large part of the heavy traffic from this port passes north through the Giovi tunnel some twenty-five miles from the city. This tunnel is about two and one-half miles long, and has a very heavy grade. A part of the trains are now handled by locomotives of the Italian Westinghouse Company for which the State Railways has placed an order for forty. These locomotives, designed by Mr. Kando, are operated by two three-phase motors of one thousand horse-power, one-hour rating, at a speed of

twenty-eight or fourteen miles per hour. There is an automatic control by which the division of the load between two locomotives can be proportioned as desired, thereby overcoming the difficulty of unequal load when the wheels on different locomotives are not of the same diameter. This control, secured by changing by compressed air the level of the water in the water-rheostat connected in the secondary circuit of the motor, is ingenious and effective.

It is understood that the whole traffic, passenger and freight, of the State Railways on the Giovi line; and also on the two lines south and west from Genoa, aggregating about 100 miles, including the extensive stations and yards in Genoa, will soon be operated electrically. The leading reasons for electrification are usually to eliminate steam locomotives from tunnels or to handle greater traffic over a given line or for economy in operation. All three of these reasons apply to the Italian situation. Coal has to be imported from England, while water-power is generally available.

The double trolley overhead system has been carefully worked out by the Italian State Railways and looks more simple in the air than it does on paper. The working appears to be quite successful under the conditions of operation, namely, three thousand volts and thirty miles per hour. The large way in which the Italian State Railways is proceeding with the electrification of its lines—as the number and size of locomotives now being built considerably exceeds the aggregate of all prior three-phase operation—gives reassurance of the substantial progress of electric locomotives.

At the Oerlikon works, near Zurich, I was fortunate to see just ready for shipment a single-phase locomotive for the new Berne-Loetschberg-Simplon line. The locomotive is supplied with two one thousand horse-power motors. Each is geared to a crank shaft which is connected by side rods to the driving wheels. The whole locomotive had a pleasing and business-like appearance.

In Berlin I found that the Prussian State Railways, after investigations covering several years, including the operation of its suburban service near Hamburg, is proceeding with the single-phase system, and has purchased locomotives from each of several companies which will be put into service at once on the line between Dessau and Bitterfeld with the intention of extending the electrification to Magdeburg, Leipsig and Halle in the near future. The frequency will be fifteen cycles, which is also adopted for the Loetschberg line in Switzerland, for which the Allegemeine Company as well as the Oerlikon Company is furnishing a locomotive. The

locomotives for the Dessau-Bitterfeld line are being made both for high speed passenger service, having a maximum speed of about seventy-five miles per hour, and for freight service at a maximum speed of about thirty-five miles per hour. For this road the Bergman Company is building a locomotive equipped with a single motor having a one-hour rating of fifteen hundred horse-power. The Allegemeine and the Siemens-Schuckert Companies as well as some other makers have also received orders for locomotives for this line.

I was informed that the Prussian, Bavarian, Swedish, Austrian and Swiss Federated railways had all studied carefully the possibilities of the single-phase system, and as the result the Prussian government would shortly open the electric service for which the foregoing locomotives have been purchased; that the Swedish State Railways, after tests with several locomotives, is electrifying its line between Kirun and Riksgransen, and that the Bavarian State Railways is preparing plans for the single-phase system on one of its lines.

Six heavy single-phase locomotives have been ordered for the Mittenwald Railway in Austria, and the Southern Railway of France has purchased thirty Westinghouse single-phase motor cars, and heavy locomotives from each of several companies. The aggregate number of heavy single-phase locomotives in Europe does not equal the number used by the New York, New Haven & Hartford Railroad, but it is significant that many railroads are purchasing a few locomotives, usually dividing the order between different manufacturers, and that many makers are active in building single-phase locomotives. This apparently indicates a decision to employ the single-phase system, followed by a comprehensive method of finding the best types of locomotives.

I found all large locomotives equipped with side rods, and none with gears except the one which has been described.

The motor cars on the Blankense-Hamburg-Ohlsdorf line, which has been in operation for several years, appear to be operating well and giving an excellent service. The motor cars have four-wheeled trucks at one end, carrying two 200 horse-power Allegemeine motors. At the other end of the car is a two-wheeled truck. There is a companion car having similar trucks, but carrying no motors, except for the air compressor. One end of this car is equipped with control apparatus so that the two cars together can be operated

in either direction. An extension to this service, for the suburban traffic on the main line toward Berlin, is soon to be opened.

I took a ride on the Rotterdam-Haag-Scheveningen line which is operating trains of high-grade motor cars equipped by the Siemens-Schuckert Company which seemed to be giving excellent high-speed service.

In England the London, Brighton & South Coast Railway which is operating about twelve miles of line is soon to be extended to include twenty miles more. This road was equipped by the Allegemeine company and built according to the advice of Mr. Philip Dawson who, I understand, will present a paper describing its equipment and operation in the near future. This single-phase road is said to have had a phenomenal increase in the number of passengers carried over that in previous operation by steam locomotives and to be giving a most excellent account of itself not only in regularity and promptitude of service and in economy in power consumption, but also in financial returns.

Glancing over a list of the twelve or fifteen three-phase roads and the twenty-five or thirty single-phase roads in Europe, I find that there was much that I did not see, but what I did see was impressive of present progress and of the large plans which are being made for the future. Practically all interest seems to be directed toward alternating-current development for heavy traction, either single-phase or three-phase, and at a low frequency, approximately fifteen cycles, this being accepted as the standard by several governments.

CHAS. F. SCOTT

The Centralization of Power Generation

An interesting and suggestive paper was read before the National Electric Light Association last May by Mr. H. Russell. It described the methods of the Rochester Railway & Light Company in selling electric power for agricultural uses. The Rochester Company furnishes electric power for lighting, for railways and for large industrial factories, and is now extending its sale to farms. The sale of electric power to farmers is not wholly new, since irrigation pumping with electric power has been growing in favor for some time in the West. The Rochester Company is simply following the line of commercial advantage that has been made possible by extensions and improvements in electric power systems. The great significance of their operations on the farms around Rochester lies in the recognition by

this company of the financial gain to be derived by supplying all kinds of power business from a central generating plant.

Just at present, the attention of engineers and managers is being especially directed to matters of improving power plant "load factors", of standardization of electrical apparatus especially for railroads, of combining different classes of electrical work according to their "diversity factors" and according to the hours and seasons of their power demand. It has been clearly shown that the most economical generation and use of power is obtained when large amounts of power can be applied to a great variety of work, and when standard electrical systems and apparatus provide a common source of power for all kinds of operations. The increasing use of electrical power in nearly every kind of work is causing rapid industrial and social development, and it is reasonable to expect that further experience in its economical use will result in greater developments.

The time is not far distant when electric power will be required by all classes and become a general article of trade, as are coal, or flour or railroad service at present. There will be many different classes of electric power supply, as there are now different classes of railway service, and the sale of power will be at different rates according to the class of the power, which will depend on the hours per day or the seasons of the year that the power is used, and on the quantity that is purchased, and on the reliability or freedom from interruption that is demanded, and even on the "charges that the traffic will bear", as the saying is, in the case of the useful but much-abused railroad rate-making rule.

The requirements of economy will lead to generating electricity in much larger units than is now common and the cost of its transmission over long distances will be reduced by carrying it in larger quantities. To avoid duplication, all kinds of power work will be supplied from a system of transmission lines fed from a few main sources of power. Advantages of location for cheap fuel or water-power or nearness to power-consuming centers will determine the location of generating plants, while the superior economy of large plants as compared with small ones, and the more general distribution of electric power for all kinds of work, and the cheapness and ease with which it can be transmitted, will eventually result in the use of only a few very large generating plants, each plant serving large areas and generally connected by transmission lines with other similar plants.

With the rapid increase in the use of electric power that is now in progress, and the many new applications to which it is being put, the time is fast coming when the generation and transmission and sale of electric power by large central power plants can advantageously be made an independent business, separate and distinct from all manufacturing, transportation or lighting concerns. A standard electrical system should be used to deliver power for all kinds of work, and large electric power generating companies will probably become independent concerns, without other affiliations. For it would appear that if such power-producing corporations have other affiliations, the public anti-monopolistic sentiment may be as justly directed against electric power companies owning railroads, or public lighting plants, or manufacturing concerns, as it now is against railroads owning and operating coal mines. This will especially apply to power companies which control water powers.

When all conditions are favorably met according to the best engineering skill, the power supply for all kinds of work in a state like Pennsylvania will be most economically produced from, say, about half a dozen large central power plants located at coal mines and working to some extent in conjunction with water-powers. When this condition is realized, and the rates for power are adjusted in fair relation to the cost of production of the different classes of power service and to the value of the service rendered, then the business of power generation and supply will properly become the work of corporations that will bear much the same relation to the public that railroads and coal companies and telegraph and telephone companies do to-day.

Is the art of electrical engineering sufficiently advanced at present to meet the demands of industry and commerce with an economical and generally universal power supply system? It seems to the writer that it is, and that the time has arrived to greatly increase the centralization of power generation, and to supply practically all kinds of power from a few main central sources. There is no doubt but that a comprehensive electrical power system will be developed, either through selection from present appliances or from new discoveries, that will enable all kinds of power, whether for manufacturing or for railroading or for lighting or for electrochemical work, to be supplied and distributed from a single large power system, and it appears that the time is ripe and the means are now at hand for practically accomplishing much of this work.

F. DARLINGTON

COMMUTATION AND THE INTERPOLE RAILWAY MOTOR

J. L. DAVIS

THE interpole or commutating pole principle, for eliminating sparking at the commutator, has had an extensive application in the last five years to nearly all types of direct-current apparatus, including turbo-generators and slow speed generators, stationary variable speed industrial motors and railway motors. It has not been applied to the rotary converter, because the converter has practically no armature reaction. The rotary converter with the split pole for regulating the ratio of direct to alternating current voltages has, however, interpole characteristics over certain ranges. On no classes of apparatus has the interpole construction been used to better advantage than on the variable speed shunt industrial motors where the speeds are varied in a wide ratio by changing the field excitation, and on the series railway motor where the speed is also continually varying over wide ranges. On both of these types the direction of rotation must be reversible at will without shifting the brushes.

On constant speed generators or motors, the brushes may be shifted off the geometrical neutral until a point of sparkless commutation is found. The reliability and low maintenance cost of station generators have long been a source of admiration to the railway motor designer. The beautiful polish on their commutators has put the railway motors to shame. Well designed machines of this class will commutate sparklessly from no load to full load, and will stand one hundred percent overload momentarily without injurious sparking. As far as bettering their operation is concerned, the interpole is hardly needed, and it is applied to such machines only when a non-interpole machine is limited by factors which produce poor commutation, and where its application will result in the design of a cheaper machine by the use of a higher peripheral speed of armature or larger currents per conductor.

In the railway motor the interpole feature has not resulted in the cheapening of motor of a given capacity or in the reduction of weight except in a few instances, but it is in the improved operation of the motor in service that the greatest advantages are to be found. In the direction of greatly increased reliability and reduc-

tion of maintenance and operating costs, the new motor has proven itself revolutionary in character and is the greatest single step in advance in railway motor design since the advent of the carbon brush.

Operating engineers may well inquire why the mere elimination of sparking should result in such great gains. The reasons have been more or less recognized for a long time. On analyzing records it was found that the large majority of electrical troubles on railway motor equipments arose from the faulty commutation of the current. Expensive haul-ins and interruptions of revenue-producing service resulted from flash-overs, bad commutators and break-downs of insulation. The original cause of these difficulties may be traced largely to sparking at the commutator. In addition, the sparking disintegrates the carbon brushes and burns away the copper, thus roughening and blackening the commutator. The corrosion of the copper bars leaves the mica insulation projecting above the surface, and the commutator rapidly roughens to such an extent that the brushes are thrown off the commutator at high speed with disastrous effects to both commutator and brush-holders. The carbon and copper dust filters through the winding of the motor and, as it is a good conductor, greatly reduces the insulation strength so that a break-down is liable to result. The brush-holders deteriorate rapidly under the vibration produced by the rough commutators, and brushes are broken. Both of these results add their effects to the production of flashing.

In the normal operation of a railway motor there are corrective influences at work, chiefly the polishing or abrasive action of the hard carbon brushes and high brush pressure. If a non-interpole railway motor is run at its rated load for an hour the commutator may become blackened and such a load continued steadily for a few hours would probably result in a flash-over from a rough commutator. In service, however, the heavy loads are alternated with light loads and coasting at high speed, so that during these periods the carbon brushes can overcome the corroding action of the heavy sparking in starting up. A motor operates fairly successfully and the commutator remains bright when the polishing periods overbalance the sparking periods. The margin, however, is slight and abuse may start a roughness, which goes from bad to worse. Hard or gritty brushes and heavy brush pressure are necessary to produce a polish, and these cause great wear on commutator and brush. The expedient of cutting the mica down below the surface has been found to be a great help in enabling the brush to main-

tain the polish and, therefore, a fairly good commutating condition for a period of time, but sooner or later the wear and tear in service produces inequality of action.

If sparking is eliminated at all loads encountered in service, a soft high grade carbon brush with no ash or abrasive material to cut the commutator may be used. The commutators then run without perceptible wear for several years and the life of the brush is increased enormously. The absence of carbon and copper dust in the motors allows more favorable insulating conditions, and breakdowns are fewer. Brush holders do not deteriorate as rapidly and, in general, electrical break-downs from commutating causes are reduced to a point where mechanical and other weaknesses become the principal element in depreciation.

On account of the very soft non-abrasive quality of the high grade carbon brush which has come into general use, all non-interpole motors of small capacity should have the commutator mica slotted, and it is a safer expedient to follow the same practice on the interpole motors, as under the heavy vibration and high temperatures found in service the mica may squeeze out a few thousandths of an inch and start a roughness which the soft brush can not wear down.

Beside the causes just discussed, flashing may also be produced by an inherent instability in the motor. This flashing may occur with bright commutators and is produced by interruptions and quick applications of full voltage at high speeds, such as the motor would receive in service when the circuit is broken when a car passes gaps in the third rail, by jumping of trolleys, sleet on third rail or trolleys, or failures in the control. Inductive kicks in the third rail or abnormal rises of potential above the line voltage, due to the quick blowing of a fuse or the breaking of an arc on short-circuit, are of the same nature. Excessive rushes of current through the motor are produced which the latter is unable to commutate at high speeds, especially under poor commutating conditions, and a flash is caused. When one motor in a train flashes the inductive kick in the third rail at the break of the short-circuiting arc may rise as high as 1 200 to 1 600 volts, and every other motor in the train may flash. This phenomenon does not usually manifest itself on motors of smaller capacity, as the inductive or choking-coil effect of the great number of field turns limits the maximum flow of current to a safe value until the field magnetism has time to build up and produce a counter e.m.f. in the motor which cuts the current down to its previous running value. On a 40 horse-power

motor, running at high speed at one-third full-load current, the breaking of the current and a quick re-application of full voltage will cause a rush of not more than full-load current through the motor. The commutation of this current at high speed causes a "spit" under the brush, but this rarely amounts to a flash-over, unless the commutator is very rough or the vibration is very great.

On motors of a capacity as large as 125 to 200 horse-power, the desire of the designer to obtain minimum losses, weight and cost in a given space, forces him to use as few field turns as possible, only enough to provide sufficient inductance to limit the maximum flow of current to a safe value. The tendency to flash is further aggravated by the heavier sections of metal in the magnetic circuit, and by the lower resistance. The eddy currents induced in the more massive frame by the building up of the flux behind its normal ratio to the current retard its rise, and since there are fewer turns in the fields to accelerate the flux and to build up the counter e.m.f. of the motor, excessively heavy rushes of current and a powerful distortion of the field results. The maximum rush of current in a non-interpole motor of 200 horse-power capacity may reach 150 percent overload if full voltage is suddenly thrown on after an interruption of current, when running on 750 volts at one-third full-load current.

In the interpole motor, the strength of the interpole magnetization is fixed for sparkless commutation at full load. At this point it overpowers the field produced by the armature, and annuls the voltage generated in the coils which are short-circuited by the brushes. As the armature is connected in series with the interpole coils, the same current passes through both and at all loads up to a heavy overload the sparking is eliminated. The limit of overload which can be carried is fixed by the magnetic saturation of the interpole; beyond this value the sparking rapidly increases and the interpole loses its efficiency and becomes a detriment.

The commutating features of the interpole motor are utilized by the designer in greatly reducing the field strength in comparison with that of the non-interpole design. This decrease is partly discounted by the extra inductance or choking action introduced by the interpole field coils, the net result being that the motor can commutate a much larger rush of current without flashing. For instance, a 200 horse-power motor, running on 800 or 900 volts at very high speeds, will take a current rush of two and one-half times full load without flashing.

In the interpole design the copper is re-distributed, enough being taken out of the field coils to make the interpole coils and to add somewhat to the armature. The total weight of copper remains the same and the weight of the motor is slightly increased. The net result is a motor with better operating characteristics in the same space as before, and only slightly heavier and more costly.

RESULTS IN SERVICE

With the above interpretations, the record of over 300 000 horse-power in interpole railway motors, placed in service within the last four years, can be better understood. The rare cases in which flashing has occurred indicate that motors can flash only when the brushes are jumped from the commutator under weak brush tension or irregularities arising from the construction of the commutators.

On a large elevated system where, with the old type of motor, the flashing amounted to several hundred cases per year, commutating conditions were in bad shape and sympathetic flashes often tied up the whole system. Interpole motors were placed in service somewhat over two years ago, since which time the flashes have been so few as not to be noticeable. Electrical and mechanical troubles of all sorts have been extremely rare. It has been reported that several million car miles have been run without a motor defect which would retire the car from service. The commutators on these motors have retained a fine polish and seem to have no appreciable wear.

On another large system where the motors have been in operation for nearly three years, flashes from all causes and breakdowns are negligible. It seems as though the commutators take on a high glaze which prevents wear. The average brush life in this case runs from 50 000 to 150 000 miles.

On nearly 1 000 motors on a large city system the commutators have remained highly polished during two years' operation. The wear is hardly noticeable, and no commutators have had to be turned down on account of commutator troubles. The majority of motors are still operating with the original brushes. The motors are free from carbon and copper dust. The total cost of maintenance of these equipments has averaged about ten percent of that of the equipments of older type motors in service for the five years previous. Most of this saving must be attributed to the use of the interpole.

Similar results are reported from roads employing motors from 40 horse-power and up, in all classes of service. The records of motors operating on 1 200 volt circuits have been recently published and indicate the same results. These results are difficult of comprehension by the operating engineer who has had to live with his troubles on older equipments by night and by day, and who expects but little improvement. To-day the interpole railway motor has substantiated its claims as a most dependable piece of electrical apparatus in a place where reliability has been most needed.

POSSIBILITIES

Apart from rendering the 1 200 volt direct-current system possible, there is another attractive possibility which offers great flexibility in certain cases where cars are called upon to operate at very low speeds and also at very high speeds, and which may be obtained by the variation of the speed by field control. In very congested city service many starts to the mile are made and high speeds are required by the outlying portions to make a good average schedule speed. The gear ratio selected is a compromise, and is particularly unfavorable in power consumption, due to the rheostatic losses caused by the frequent accelerations in the congested district which require large draughts of current for the necessary tractive effort, and is also unfavorable on the longer runs, as it does not permit much coasting to save power, since the maximum speed of the equipment is required with power on all the time in order to maintain the schedule. Under such extreme conditions field control permits the use of a smaller pinion and less current consumption with a strong field for a given accelerating power, which gives better economy in short runs. A higher speed on light fields can be obtained for the long runs, so that the same schedule speeds may be maintained with a saving in power amounting to from ten to twenty percent, depending upon the conditions.

In very high speed interurban operation, interchangeability of equipment demands the use of the same cars with the same gear ratio for local as well as for limited service. The resultant poor economy and overheating of motors with a high speed gear ratio when used in local service, is well known, and in this class of service field control should prove a welcome gain. Equipments with field control, however, are in the experimental stage and have not been applied to general service.

The advantages of the interpole design and field control have been worked out to the greatest degree in the design of the motors

for the Pennsylvania locomotives. These motors, which are the most powerful ever built for railway operation, were designed with the special object in view of commutating the enormous currents which they will be called upon to carry when accelerating the heavy trunk-line trains of the Pennsylvania Railroad up the two percent grades in the tunnels under the Hudson and East Rivers.* The design of the interpole is so liberal that a load of 2 500 horsepower is developed with the weakest field without appreciable sparking at high speeds. At the same time, when running at 70 miles an

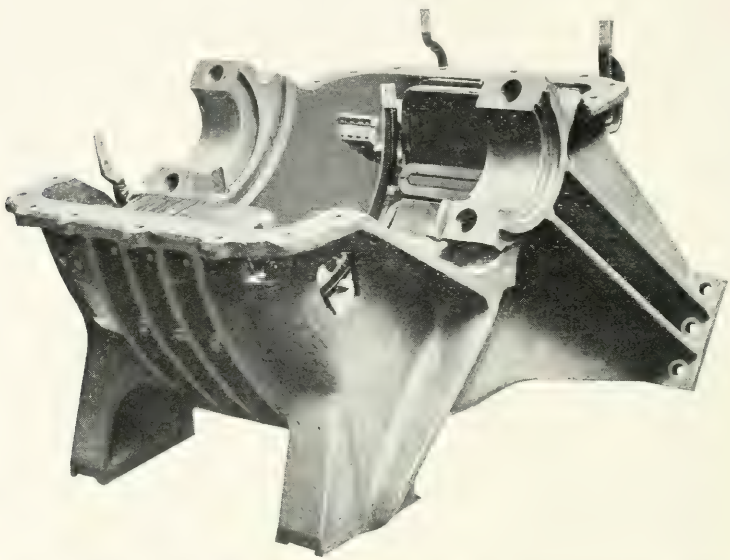


FIG. 1—DETAIL VIEW OF LOWER HALF OF FIELD OF LARGE INTERPOLE MOTOR
Pennsylvania locomotive.

hour, on 725 volts on the highest speed notch and the weakest field, the gaps in the third rail on the Long Island Railroad, which occur every few hundred yards, are crossed without any spitting at the brushes.

During acceleration the power consumption is reduced to 55 percent of what it would be without field control, and thus a large saving is affected in the resistors. The locomotive has eight run-

*See article by Mr. H. L. Kirker in the Journal for Sept., 1910, p. 668 For illustration of armature of one of these motors, see p. 826 of the present issue.

ning notches instead of three, as would be given by an ordinary four motor equipment. This range of tractive effort, while running in multiple on full voltage, and with no resistance in series, approaches the control of an alternating-current locomotive, which has 97 percent economy in acceleration, and controls by varying the voltage applied to the motor. A tractive effort of 69 000 pounds at 24 miles per hour, to 5 500 pounds at 76 miles per hour, is the great range on the Pennsylvania locomotives. The New York Central locomotives range between 47 000 pounds at 32 miles per hour and 5 500 pounds at 63 miles per hour.

Beside furnishing a greater number of running notches which is of extreme importance in the slow accelerations of locomotive service, the use of a simple two-motor equipment for power and

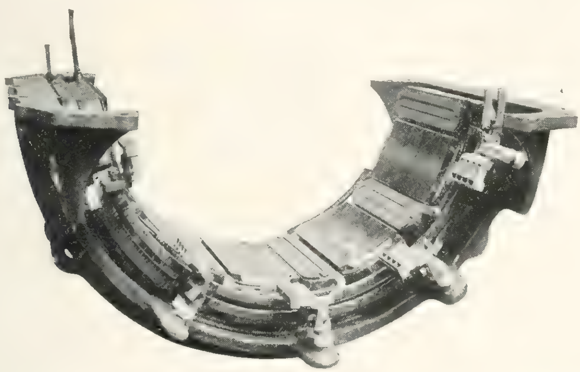


FIG. 2—DETAIL VIEW OF UPPER HALF OF FIELD OF LARGE INTERPOLE MOTOR
Pennsylvania locomotive.

speeds never before attempted has been rendered possible. The design would have been impracticable without the interpole construction. The results in operation of these locomotives have been most gratifying and speak well for this advance in the application of electricity to trunk line service.

THEORY OF THE INTERPOLE

The current in the windings of an armature produces a magnetic field which is a maximum in the space between the main field coils. The coil undergoing commutation, whose ends are connected to bars under the brush, has its sides lying in its armature flux, and in the rotation through the flux an active voltage is generated between the bars. In addition to this voltage there is another in the same direction, produced by the reversal of the flux induced by the

current in the coil undergoing commutation. As the current is reversed in the coil while the bar is passing from under the brush, the magnetic lines which exist principally around the slot in which the coil lies, are also reversed, and this is like the "kick" obtained in opening a current-carrying circuit. The voltage produced by armature reaction adds to the slot reactance voltage to form the voltage which produces the sparking.

If a small pole and coil is placed between each of the main poles and current sent through the coils so as to oppose the armature magnetization, the field due to the armature reaction can be completely neutralized in the zone of commutation. Beside this an additional excitation is needed to drive sufficient flux into the armature against the armature magnetization so as to neutralize the flux

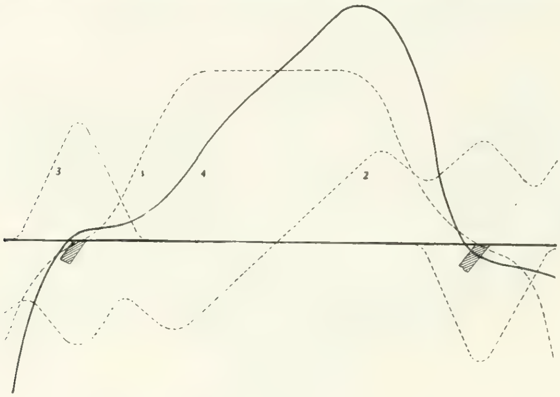


FIG. 3—CURVES SHOWING MAGNITUDE AND SHAPE OF MAGNETIC FLUXES IN INTERPOLE MOTOR

1—Produced by field coil alone. *2*—Produced by armature alone. *3*—Produced by interpole alone. *4*—Produced by field, armature and interpole acting together—algebraic sum of *1*, *2* and *3*.

around the slot when the current in the armature coil is reversed. These extra turns are known as the over-compensating turns, and enough are added not only to neutralize the reactance voltage, but to add a small voltage in a favorable direction under the brush for a purpose which is explained later.

The voltage between the bars under the brush can be measured by means of two hard graphite pencil points which are mounted with the points the width of one commutator bar apart. The leads of the pencils should be connected to the two terminals of a 5-15 volt direct-current voltmeter. The pencil points should be held on the commutator at the middle, and at the toe and the

heel of the brush. The field around the armature may be explored by progressing around the commutator, taking readings at intervals of one bar. Fig. 3 shows the magnitude and the shape of the magnetic fluxes, produced by the different windings at low iron saturations. Curve *1* shows the flux produced by the field coil, when the current is passed through the field coil alone. Curve *2* shows the flux produced by the armature alone. Curve *3* shows the flux produced by the interpole alone. The full line *4* shows the flux produced by the field, armature and interpole acting together, and is the algebraic sum of curves *1*, *2* and *3*.

At high magnetization, however, the iron of the teeth, pole tips and interpole become more or less saturated, and this flattens out the main body of the flux and may change the magnitude and sign of the voltage under the brush.

In the series motor the windings are connected all in series, so that if the iron in the interpole core does not become saturated the proper adjustment of the interpole which gives sparkless commutation at one current and speed will give it at all currents and speeds. The magnetization of the interpole is generally greater than that of the main field, so that it creates a powerful field between the interpole core and the main field core. This leakage flux tends to saturate the interpole core, so that with thin interpoles the saturation point is reached earlier than with thick.

The reactance flux around the slot in the armature increases in proportion to increase in load, for this circuit has low densities and never reaches saturation. With increasing overloads the point is reached where very little more correcting flux can be forced into the armature by the interpole, while the reactance voltage steadily increases. The sparking gets stronger and stronger, while at an excessively heavy overload the sparking may be worse than if there were no interpoles at all. At this point the saturation of the interpole practically cuts it out of function, and the armature is left with the interpole pole tip partially closing the slot and increasing the reactance flux and voltage. This is illustrated by the curves in Fig. 4, which show the voltages under the brush when the motor is run at constant speed and the load is varied. Curve *4* shows the volts generated under the brush, by the over-compensating turns on the interpole if the latter does not become saturated. Curve *1* shows the voltage between bars actually generated by a saturated interpole. Saturation, in this case, begins at 100 amperes. Curve *2* shows the

reactive volts generated by the reversal of the current. This is calculated from the slot dimensions and relation to the interpole tips. Curve *3* is produced by subtracting *2* from *1*, and represents the volts under the brush observed when the motor is connected up and run at constant speed.

It may be seen that at 100 amperes there is one volt in a favorable direction, and at 200 amperes the reactance balances the interpole. Owing to the bending over of curve *1*, the volts under the brush reverse and rapidly increase, due to the increasing reaction. Curve 5 of a corresponding non-interpole motor is given for comparison. At 550 amperes the interpole is no better than the non-interpole, and beyond this it is worse.

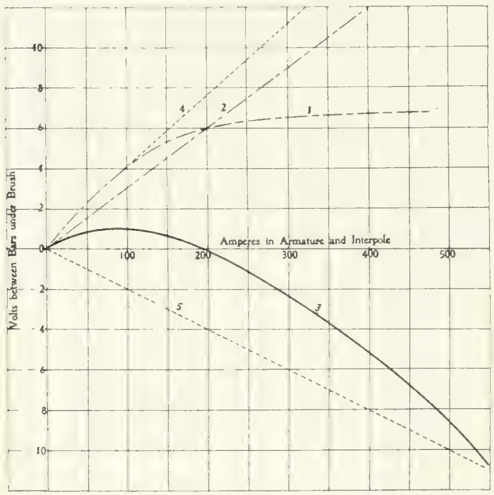


FIG. 4—VOLTS IN COIL WHEN SHORT-CIRCUITED DURING COMMUTATION. CONSTANT SPEED; VARYING LOAD

1—Generated by interpole flux. *2*—Generated by reversal of reactance flux around slot. *3*—Difference between *1* and *2*—volts between bars under the brush. *4*—Generated by overcompensating turns on interpole when not saturated. *5*—Non-interpole—given for comparison.

As noted before, the breaking and making of a high voltage on a motor running at high speeds, will produce a great rush of current before the field can build up and choke down the current to its previous running value. As the eddy currents in the solid frame retard the rise of the flux in the main field, they also retard the interpole field. The reactive flux, however, being chiefly in laminated iron, rises in proportion to the armature current, so that less effect is obtained from the interpole with exceedingly rapid changes of current than with slow changes. For this reason, it is better to slightly over-compensate with a small voltage of favorable sign under the brush, so as to get proper correction for rapid changes of current. German silver shunts around the interpole coil, or short-circuiting shields of metal around the pole tips, prevent the proportionate rise of the flux with the current, and hence should not

be used. The limit of practicability of the interpole design is determined mainly by the degree in which the equalization holds during sudden rushes of current, either by exceeding the limits of a saturated interpole, or by a lag in the rise of interpole flux behind the armature current. The over-compensation necessary depends upon many factors that are becoming better understood as the diversity of designs multiply.

The following tentative theory of action fits many facts, and is offered with the view of simplifying the problems that arise in design:—

It may be assumed as a postulate that if no voltage is produced in a short-circuited coil, the instantaneous value of the flux, controlled by the coil, cannot change during the commutation. It is known, however, that the flux around the slot carrying the coil *does* change and reverse. Therefore, the effective flux introduced by the interpole must be equal and opposite to the slot flux and must change as the slot flux changes. The instantaneous algebraic sum of the fluxes must be nearly zero at all periods near the commutation point.

The direction of currents in the interpole field and the armature coil, on coming up into commutation under the interpole in a right hand direction, is shown in Fig. 5. As it is desired to investigate only the change of that element of the total flux which is produced by the one coil being commutated, the main and armature fluxes can be disregarded, as the first has no effect, and the armature flux is balanced by the compensating turns. Therefore, only the over-compensating turns placed on the interpole, and only one coil on the armature, need be considered. The flux due to the armature coil alone is represented by a and a', which reverses with the current. The flux produced by the over-compensating turns is represented by b and c, and each has the same value as a or a'. The value of b and c is that part of the total interpole flux which is embraced in the angle of commutation swept over by the coil while the current is reversing. This depends upon the width of the commutator bar and the brush. On this assumption, the flux b c will change in the same time as the fluxes a, a' and in an opposite manner, so that no voltage is generated in the coil. Within the coil, b and c plus a and a' equal zero effective flux. In section *2*, b and a are shown in opposite directions in tooth T, and likewise b' is beginning to neutralize a' in tooth T'.

In section *3*, the fluxes in teeth T and T' are neutralized and

b and b' do not change their values by linking with a and a', as the current in the armature coil adds to the magnetization of the interpole in the same amount as is necessary to produce the same flux through the greater reluctance from the tip of the tooth to the interpole. c is opposite to a', so that the net flux in the coil is still zero. The current in the coil begins to die out as rapidly as the interpole comes over the coil, as shown in section *4*. The current in the coil

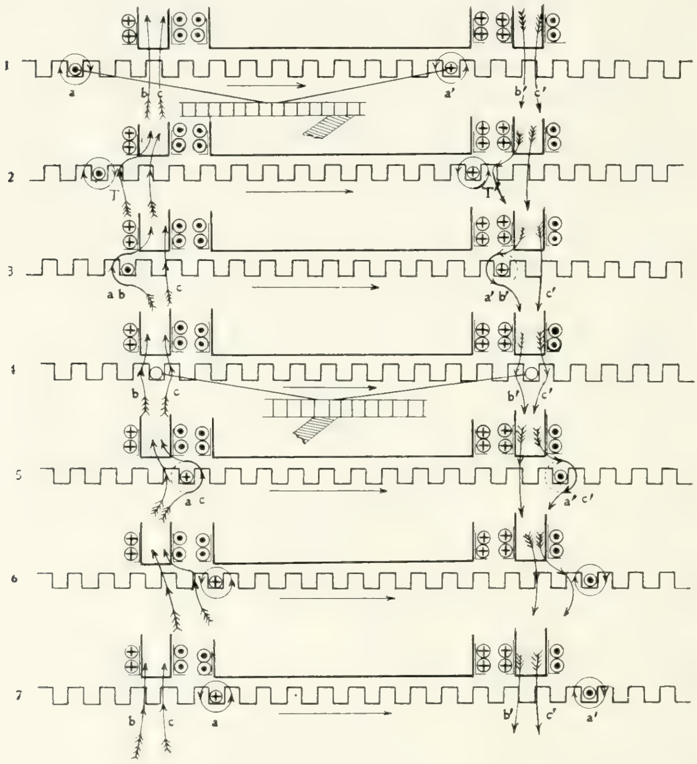


FIG. 5—DIRECTION OF CURRENTS AND FLUXES IN INTERPOLE AND ARMATURE DURING COMMUTATION

Illustrating theory of the interpole.

is zero, so there is no flux due to it. The interpole flux is divided on both sides of the coil. It is not changed in value, as the magnetization of the armature coil vanishes as the reluctance decreases, so that the interpole ampere-turns keep the flux the same. Since b neutralizes b', the effective flux within the coil is still zero.

In section 5 the current in the coil increases in the opposite direction and helps the interpole to stretch the flux c and c' as the

interpole moves away. The flux is unchanged in amount as the current increases as fast as the reluctance increases.

Sections *6* and *7* show how the flux around the slot disengages itself, and the commutaion is finally effected without the algebraic sum of the fluxes in the coil having changed.

From this it is seen that to get the best effects from the interpole with least expenditure, the sides of the commutated coil should lie under each pair of interpoles or under all of them. If one side alone is under an interpole, nearly twice the over-compensating turns will have to be put on each interpole. This occurs when the width of the coil is greatly different from a full pole pitch. It also happens when the pole is narrow and the slot is under one interpole and the tooth under the other, so for symmetry, the number of slots should be divisible by the number of poles. In multiple windings, this will give greater economy of interpole design. Series windings with a symmetrical number of slots would require less over-compensation than with unsymmetrical. It is rarely feasible, however, to take advantage of this relation.

The length of the interpole along the core does not matter materially, so long as the proper corrective flux can be produced without over-saturation of the interpole, but the thickness is of greater importance.

Experience is rapidly setting the limits to which the designer can go, and the device is now amenable to calculation, so that exact designs will be less difficult in the future.

CONDENSER TYPE TERMINALS

A. B. REYNDERS

THE most serious difficulty encountered in the design of transformers and other apparatus for high potentials is in the insulation of the terminals where they pass through the case. Failure is liable to occur either by puncturing the insulation separating the live metal conductor from the case or by creepage over the surface of the terminal from the conductor to the ground. The ideal conditions for maximum insulation strength are obtained when the potential gradient (volts per millimeter) through the material is constant, and when the potential gradient along the surface of the terminal from the line to ground is also constant. In the ordinary type of insulated terminal, consisting of one or more homogeneos materials surrounding a metallic rod, the potential gradient both through the material and along the surface is not at all constant. In order to make such a terminal safe, it is necessary to keep the potential gradient at or below the amount which will be safe for its weakest point.

DISTRIBUTION OF POTENTIAL

The approximate distribution of potential through the dielectric of an ordinary terminal is shown in Fig. 1. It will be seen that the slope of the curve at the upper end is much greater than at the lower end, which means that the stress on the layers surronding the rod is much greater than the stress on the outside layers. The higher the voltage the greater this difference becomes, hence a point is soon reached where the amount of material required in order to work the inside layers at a safe stress becomes enormous, and the size and cost become prohibitive. One method of overcoming this difficulty has been suggested and put into practice by Messrs. Gorman, Jona, and others. It consists in using several different materials to surround the conductors instead of one homogeneous material. The materials are arranged according to their various specific inductive capacities, that having the highest capacity surrounding the inside rod. It is a well known fact that if materials having different specific inductive capacities are arranged in series and a voltage is impressed across the series, the greatest stress will be thrown on that material having the lowest specific inductive capacity. This

is illustrated in Figs. 2 and 3. The fall of potential in Fig. 2 is uniform between the terminals *A* and *B*, the specific inductive capacity being uniformly one. If a glass plate be introduced in the gap, since its specific inductive capacity is greater than unity, the potential curve will be as shown in Fig. 3. These figures make it plain that the introduction of the glass, with a high specific inductive capacity, has thrown a stress across the remaining air greater than was present before. This means that, if originally the air was near the breaking down point, the insertion of a glass plate, instead of increasing the dielectric strength of the air, may actually cause a breakdown. Hence, if insulating materials are inserted, a proper selection with regard to their specific inductive capacities must be made.

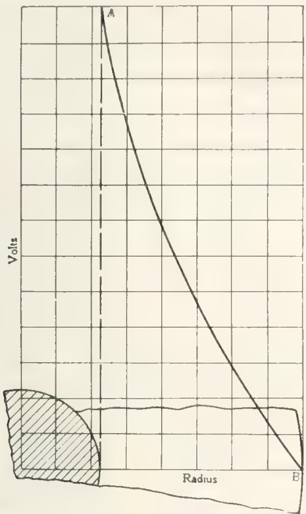
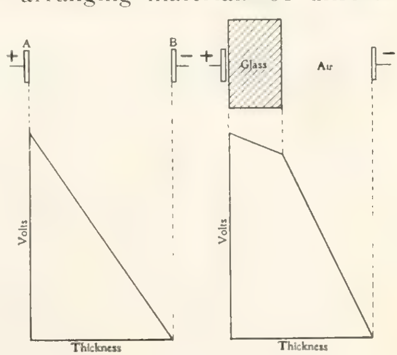


FIG. 1—POTENTIAL CURVE THROUGH THE DIELECTRIC OF A CABLE OR TERMINAL USING HOMOGENEOUS INSULATING MATERIAL

As stated above, the potential curve of an ordinary terminal, instead of being a straight line, as in Fig. 2, becomes a logarithmic curve, as shown in Fig. 1. It may readily be seen that by properly arranging materials of different specific inductive capacities the logarithmic curve of Fig. 1 may be straightened out, as shown in Fig. 4. This is the method described by Mr. Jona in a paper read before the International Electrical Congress, held in St. Louis in 1904.



FIGS. 2 AND 3

Assuming that the necessary puncture strength can be obtained by working the innermost layers at a sufficiently low unit potential stress or by grading the insulation according to its specific inductive capacity, a more serious difficulty will be encountered from creepage over the surface. Fig. 5 shows the differences of potential over the surface of an ordinary terminal measured at distances

two inches apart by the method shown in Fig. 6. In making this test, two movable wire rings, surrounding the terminal and spaced a distance of two inches apart, were connected to an adjustable spark gap. A difference of potential from a testing transformer was applied between the inner metallic tube and the metal cylinder, the point of mounting which is normally at ground potential. The spark gap was then adjusted until it would just allow a spark to pass and the spacing of the gap measured. The rings were then moved to successive positions at intervals of two inches along the terminal and corresponding readings taken. These spark gap values were then translated into equivalent kilovolts, on the basis of which the curve, Fig. 5, was plotted. The uniform distribution line indicates the corresponding potential stress per unit spacing which would be obtained along the surface with an ideal terminal.

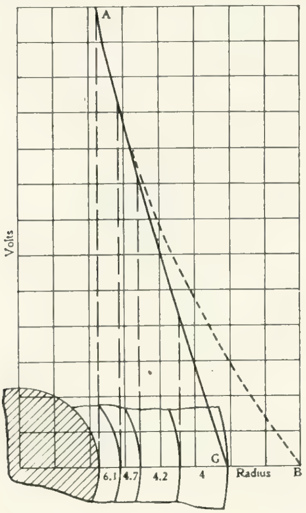


FIG. 4—POTENTIAL CURVE THROUGH DIELECTRIC USING INSULATING MATERIALS OF VARIOUS SPECIFIC INDUCTIVE CAPACITIES

DISTRIBUTION OF POTENTIAL IN ACTUAL PRACTICE

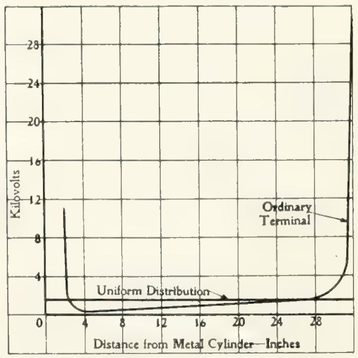


FIG. 5—POTENTIAL GRADIENT (VOLTS PER UNIT LENGTH) OVER SURFACE OF AN ORDINARY TYPE TERMINAL

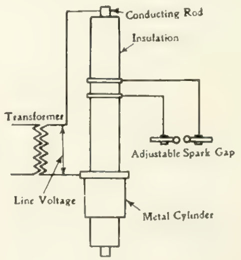


FIG. 6—METHOD OF MEASURING POTENTIAL GRADIENT OVER SURFACE OF TERMINAL

The nearest approach to the ideal conditions where the volts per millimeter are constant throughout the thickness of the di-

electric, and also over the surface between live parts and ground, has been secured by the use of what is now known as the condenser type of insulation. Essentially this method of insulating the terminals consists in surrounding the central high-tension conducting rod with a number of concentric condensers of predetermined capacity, arranged so that in effect they are connected electrically in series. Such an arrangement has been suggested in part by Messrs. Ryan, Smith, and others, but particularly by Mr. R.

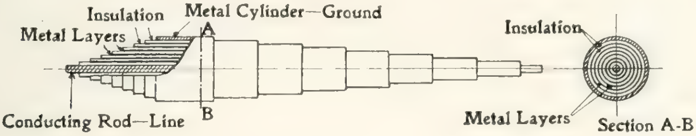


FIG. 7—CONDENSER TYPE TERMINAL

Nagel in an article published in "*Electrische Bahnen und Betriebe*," for May, 1906.

It is a well known fact that if a voltage be impressed across a number of condensers connected in series, the voltage across any one condenser will be inversely proportional to its capacity. If there are n condensers in series, each one having the same capacity, the voltage across any one condenser will be $1/n$th of the total voltage. Furthermore, in order to obtain the maximum efficiency from the insulating material, every particle should be subjected to a stress proportional to its strength. Hence, if a homogeneous ma-

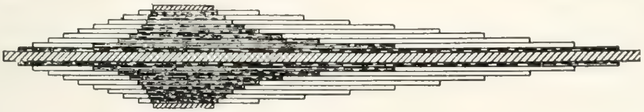


FIG. 8—CONDENSER TYPE TERMINAL

Layers of insulation of equal thickness. Shaded portions show equal capacities throughout. Full lines show equal capacities on inside and outside layers and capacities increasing towards center of insulation thickness.

terial is used throughout, which is of immense advantage commercially, then each particle should be under the same stress as every other particle. This means that, in the series of concentric condensers employing homogeneous material, in order to use the material economically, each and every one should have the same capacity.

A terminal designed according to these principles is shown in Fig. 7. The center rod is of metal and is surrounded by a layer of insulating material which is covered with a thin layer of con-

ducting material, such as tinfoil. Alternate layers of insulating and conducting material are successively applied until the proper number of concentric condensers is obtained. Towards the ends the terminal is tapered off in steps, one step at the end of each metal layer. By this arrangement of metal cylinders the potential difference between them is fixed and, hence, may be kept within the limit of the puncture strength of the insulation; moreover, as the edges of each metal layer extend to the edges of the cylinder of insulation immediately surrounding it, the difference of potential along the surface is definitely fixed and, as a maximum, may be made equal to the puncture strength of the surrounding medium (air or oil). From a manufacturing standpoint it is desirable to make the steps all equal, and to use equal thicknesses of insulating material between the conducting layers. This is possible, but very inefficient owing to fundamental difficulties; hence a compromise is usually made.

FIG. 9 — CONDENSER TYPE TERMINAL FOR 88 000 VOLT POWER TRANSFORMER

The capacity, in electrostatic units, of two concentric cylinders of equal length is expressed by the formula—

$$C = \frac{Kl}{2 \log \frac{r_2}{r_1}}$$

From this formula it may be seen that to vary the capacity it is necessary to vary either K the specific inductive capacity, l the length of the conducting cylinders, or r_1 or r_2, the radii of any two consecutive conducting cylinders, which is equivalent to varying the thickness of the insulation between the conducting metal cylinders. With the commercially available materials suitable for making condenser terminals, K cannot be varied to any appreciable extent, although it may be possible and certainly is highly desirable to secure materials having a great difference in the value of K, as will be explained later. Accordingly, the alternatives remain of securing the desired capacity by varying the length or the thickness of the insulation or both.

Assuming that the material is homogeneous and of constant thickness, the ideal condition, i. e., subjecting each particle to the

same potential strain, may be obtained with metal cylinders of equal capacities, equally spaced throughout the dielectric, by varying l. In order to secure equal capacities in this way it would be necessary that the ends of the tinfoil layers form a logarithmic curve. It is obvious that if equal potential differences are to be secured between the cylindrical metal plates, then the distances between the ends of the tinfoil should be equal, in order to prevent creepage failures, which means that the ends of the tinfoil layers should lie on a straight line, instead of a logarithmic curve; hence, although the conditions for puncture are provided for, the proper conditions for creepage become impossible of fulfillment. (See Fig. 8.) The best that can be done is to make the inside and outside condensers of equal capacities and cause all other tinfoil layers to end in a

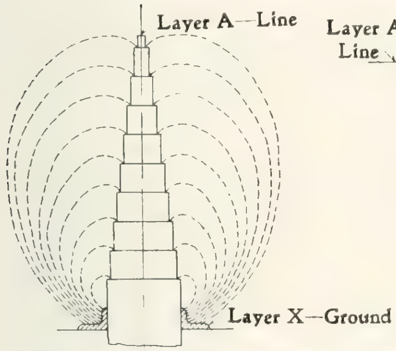


FIG. 10—PROBABLE STATIC FIELD ABOUT A CONDENSER TERMINAL

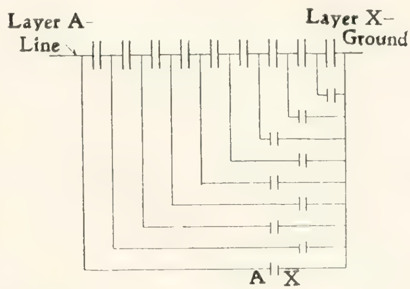


FIG. 11—DIAGRAMMATIC ARRANGEMENT OF CONDENSERS EQUIVALENT TO FIG. 10

straight line joining these points. With such an arrangement the capacities of the various condensers increase from both the inside and the outside towards the center of the insulation thickness. In other words, the material at the center of the thickness of insulation is not worked as hard as the outside, hence there is a corresponding waste.

MOST ECONOMICAL ARRANGEMENT IN ACTUAL PRACTICE

A little study will show that in order to produce a terminal with the most economical use of materials employing *equal thicknesses* of a homogeneous dielectric, the outside diameter must not be much greater than the inside diameter; accordingly, the tendency is toward a long terminal of comparatively small outside diameter.

It has been found that a far more economical terminal can be

made from homogeneous dielectric materials by varying the lengths of the cylinders in uniform steps and allowing the thickness of the material to vary, even though the thicker layers cause a slight waste of material. Such a terminal is shown in Fig. 9. In general, it produces a terminal larger in diameter and shorter in total length than the design employing equal thicknesses of material.

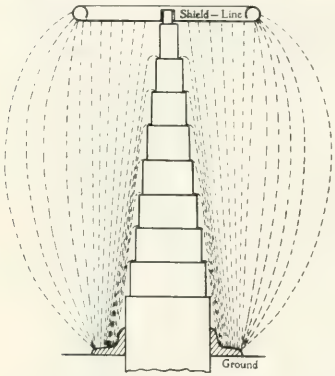


FIG. 12—PROBABLE STATIC FIELD SURROUNDING A CONDENSER TERMINAL EQUIPPED WITH A LARGE SHIELD

The ideal condition for the economical use of material (though not necessarily so from the manufacturing standpoint) can be secured by having equal steps for creepages and equal thicknesses of dielectric, and varying *K*, the specific inductive capacity of the material, in order to obtain equal differences of potential between metallic surfaces. Unfortunately, because of the fact that the specific inductive capacities of the materials commercially available for making these terminals vary so slightly, any advantage from the use thereof is lost, due to variations in manufacture. This, then, forces the use of one or the other of the two methods discussed above.

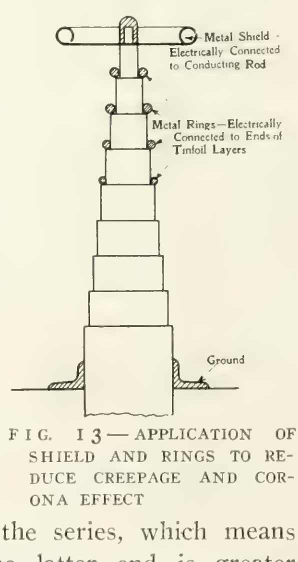


FIG. 13—APPLICATION OF SHIELD AND RINGS TO REDUCE CREEPAGE AND CORONA EFFECT

The end sought has been to obtain equal capacities throughout the series of condensers. In practice it has been found that equal capacities obtained by calculation of concentric cylinders do not give equal potentials between the metal cylinders, due principally to the leakage capacity to ground. This leakage is probably as shown in Fig. 10, and is equivalent to the arrangement of condensers shown in Fig. 11. The net result of this arrangement is an increase of capacity of those cylinders nearest the ground and a decrease of capacity of those at the conductor (inner) end of the series, which means that the stress between cylinders at the latter end is greater than calculated and that at the ground end is correspondingly reduced. To compensate for this effect, the capacity

of the line end is made greater than would otherwise be necessary, or else, when space permits, a large metal shield is used on the end of the live metal part, the effect of which is to change the leakage lines from curves (Fig. 10) to straight lines, as shown in Fig. 12.

FIG. 14—CONDENSER TYPE TERMINAL FOR 300 000 VOLT TESTING TRANSFORMER. METAL SHIELD AND RINGS ARE USED, AS SHOWN IN FIG. 13

USE OF METAL RINGS, SHIELDS AND BALLS

There is still another disturbing element in the design of the condenser type of terminal, arising from the fact that the edges of the tinfoil at the ends of the steps are sharp. At very high voltages the stress on the surrounding medium (air or oil) may be above the strength of the medium; hence corona, or even flashes, may occur. It may be taken as a fact that the safest operation is obtained when no corona is present, and in order to prevent its occurrence the stress must be lowered by avoiding sharp points upon which concentration of potential might occur. This is accomplished by the addition of metallic rings electrically connected to the ends of the layers of tinfoil and the use of shields and balls on the extreme ends. See Fig. 13. The cross-sectional diameter of the rings and the diameter of the balls and the shields must be such that the stress on the layer of air or oil in immedite contact therewith is well below the maximum working strength of the medium. It has been found that a shield of large diameter with edges of large diameter has a marked effect in reducing corona on the surface of the terminal. A terminal so equipped for a 300 000 volt testing transformer is shown in Fig. 14.

RESULTS IN SERVICE

The results obtained in service with terminals of the condenser type, such as described above, depend upon the manufac-

ture. The experience of many years in connection with the manufacture of high-tension terminals (previous to the application of the condenser principles) has been available in connection with the developments of the present type of terminal, and it may be stated positively that without these earlier developments the condenser terminal would have proven a failure. Terminals of the condenser type, such as described above, have now been manufactured for about two years, and have seen service for nearly that length of time in connection with all classes of high-tension apparatus. A condenser type of terminal used in connection with a static voltmeter, in which taps are taken off from the terminal to obtain a reduction in voltage, is illustrated in Fig. 15. An application to a current transformer for 88 000 volt service is shown in Fig. 16, the particular transformers of this type having been installed and in successful service nearly two years ago.

FIG. 15—CONDENSER TYPE TERMINAL APPLIED TO 200 000 VOLT STATIC VOLTMETER WITH WHICH THREE VOLTAGE RANGES MAY BE OBTAINED

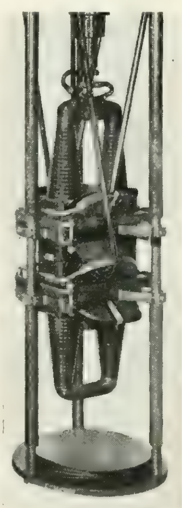


FIG. 16—CONDENSER TYPE INSULATION APPLIED BETWEEN PRIMARY AND GROUND OF AN 88 000 VOLT CURRENT TRANSFORMER

OUTDOOR TYPE

For outdoor service the terminal is modified as shown in Figs. 17 and 18. In Fig. 17 that portion of the terminal projecting into the air is covered with porcelain, and the space between the porcelain and the tube is filled with a solid insulating material. The terminal shown in Fig. 18 is for the same service, but differs from the other in that the portion extending into the air, instead of being covered with porcelain, has a metal pan or bell at the end of each strap, electrical-

ly connected to the corresponding metal cylinder. The metal bells are separated by glass or porcelain cylinders surrounding the tube, each being of the same length as the corresponding step between the tinfoil layers. This type of terminal is light, and will stand rough handling. Through its successful development the problem of broken insulators is entirely solved.

WHY CONDENSER PRINCIPLE CANNOT BE USED FOR ALL FORMS OF INSULATION

The question naturally arises as to why the condenser type of insulator cannot be applied to forms other than cylindrical. For instance, if in a stack of insulating plates layers of tinfoil be introduced, why is not the dielectric strength of the stack greater

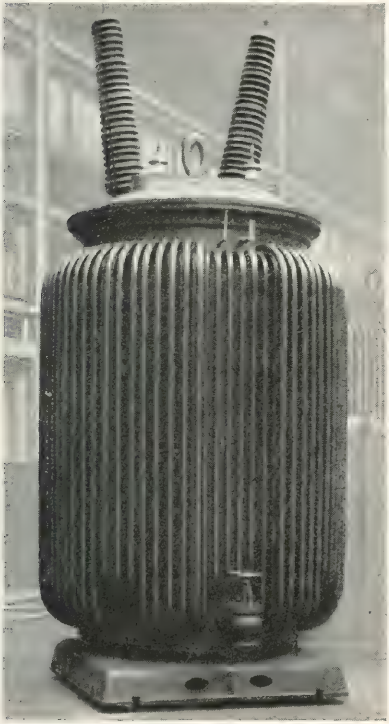


FIG. 17—OUTDOOR TYPE CONDENSER TERMINAL APPLIED TO 100 000 VOLT POWER TRANSFORMER
Illustrating use of porcelain bells.

FIG. 18—OUTDOOR TYPE CONDENSER TERMINAL FOR 44 000 VOLT SERVICE
Metal pans.

after the insertion of the tinfoil than before? The facts are that, instead of being a benefit, the introduction of the tinfoil will be found to be detrimental. If a difference of potential is applied to two flat plates separated by a homogeneous insulating material, the curve of potential will be found to be a straight line, as shown

in Fig. 2. As a straight line gives the best possible condition, the introduction of tinfoil is of no benefit. On the other hand, if there are any weak spots in the insulation, it is clearly evident that the presence of intervening sheets of tinfoil will have the effect of lining them up, and hence the possibility of failure by puncture will be greatly increased. Moreover, it is practically impossible to pile a stack of plates and eliminate the air between. This air breaks down under continued high potential stress, forming corona and heating the insulation until failure occurs. On the other hand, in the case of a terminal consisting of simply a central round wire or rod surrounded by concentric layers of insulation, the curve of potential through the insulation instead of being a straight line is a curve, as explained in connection with Fig. 1. The introduction of the metal layers tends to change the curve to a straight line. The danger of lining up the weak particles exists in this case as well as in the case of the flat plates just considered, but the great gain obtained by the straight line distribution allows for enough additional material to make this danger practically negligible.

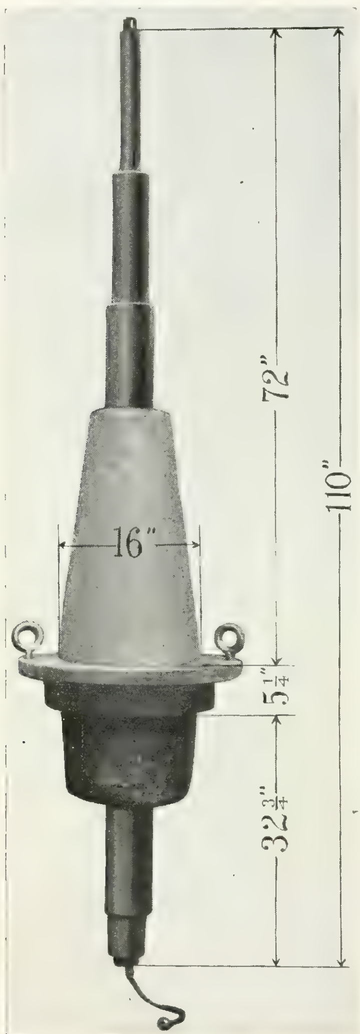


FIG. 19—"BULK TYPE" TERMINAL FOR 88 000 VOLT POWER TRANSFORMER
Showing, by contrast, space economy of condenser type.

CONDENSER TERMINAL COMPARED WITH OLDER FORMS

The great gain in material by using the condenser type of insulation in terminals is shown by comparison of the terminal shown in Fig. 9 with the one shown in Fig.

19; both were designed for 88 000 volt service and are in successful commercial use. The "bulk" type terminal, Fig. 19, withstood a test of 176 000 volts for one minute, while the condenser terminal, Fig. 9, withstood a test of 220 000 volts for one minute. The net cubical contents of the larger terminal is approximately 8.15 times that of the condenser type terminal.

RESULTS OF TESTS

In order to determine by test the value of the condenser type of insulation, two wall bushings were made, both of the same shape

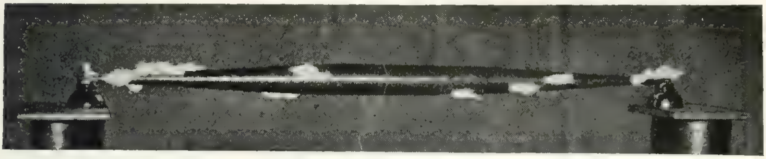


FIG. 20—CONDENSER TYPE; FIRST DISTRESS, 150 000 VOLTS; FLASH OVER, 230 000 VOLTS

and dimension, one built up with tinfoil and one without tinfoil. These were tested until they failed. They are shown at the mo-

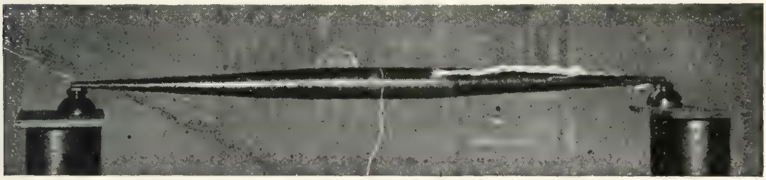
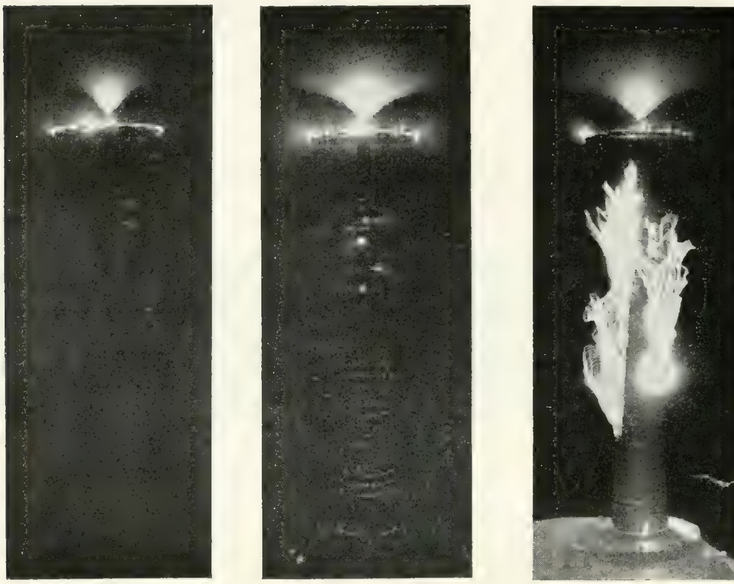


FIG. 21—"BULK TYPE"; FIRST DISTRESS, 90 000 VOLTS; FLASH OVER, 120 000 VOLTS

ment of break-down in Figs. 20 and 21. A 300 000 volt terminal of the type shown in Fig. 14, under different tests, is illustrated in Figs. 22, 23, and 24, the final break-down voltage being about 448 000 volts. The effect of the rings at the upper end of the tinfoil layers is evidenced by the absence of static discharge, while at the lower end, where no rings were applied, a glow can be seen at the end of each layer of tinfoil. This terminal was designed to suit an existing design of 300 000 volt transformer and, hence, is not as

economical or as safe a design as could be made if such restrictions had not been imposed. Transformers for testing purposes have been built, using condenser type terminals, which have successfully with-



300 000 volts for one minute. | 400 000 volts for one minute. | Breakdown—448 000 volts.

FIGS. 22, 23, AND 24—CONDENSER TYPE TERMINAL UNDER TEST

stood tests of 600 000 volts to ground, the terminals being practically without corona. These examples demonstrate the possibilities of this type of insulation for voltages far in excess of any commercial requirements.

MECHANICAL FEATURES OF ELECTRIC LOCOMOTIVES

G. M. EATON

THE natural path of approach to the mechanical problems presented by the electric locomotive has two stages. For the first stage, there is a well constructed track, with more or less familiar landmarks all the way, and on every foot of this track we can see by unmistakable signs that the steam locomotive has passed that way before. There are many branch tracks, but each one is terminated by some limiting characteristic. The physical limitations of the fireman, and the thermal limits of the fire box marked for years the end of one branch. Recently the introduction of mechanical stokers, oil burners, superheaters, etc., have enabled further progress to be made on this particular branch. In other branches, anti-smoke and anti-noise ordinances have formed obstacles insuperable for steam locomotives. The second stage is uncharted, but the pathway is roughly indicated by demands for more speed, less maintenance, double ended operation, greater safety, greater convenience, increased draw-bar pull, greater reliability, smaller operating charges—a very babel of ideals, requirements and desires. Into and over this debatable ground the electric locomotive must push its way.

It is only natural that in designing an electric locomotive, the mechanical experience gained by the building of steam locomotives should play a most important part. Every item of this experience, however, must be scrutinized in the light of the different conditions under which steam and electric locomotives are operated before it can be accepted as a safe guide for progress. Some of the more important of these contrasted conditions may be noted as follows:—

The steam locomotive is an energy generating machine as contrasted with an energy collecting machine. In addition a great volume of water has to be carried on the steam locomotive in a heavy boiler which is of necessity high above the rails. This involves a high center of gravity as inherent in the steam locomotives, while this must be won at a price in the electric locomotive. The boiler is inherently a stiff, strong element of a steam locomo-

tive, while the superstructure of the electric locomotive is inherently weak and can be stiffened only at a sacrifice of weight and cost.

The steam engine as universally applied on the steam locomotive is a reciprocating machine, while the electric motor is a rotating machine. The steam locomotive exerts a varying tractive effort at various portions of each revolution, while the electric locomotive operates with a tractive effort that is practically constant throughout the revolution.

The steam locomotive is inherently limited in its radius of action, even when working at its normal capacity, by the need for a periodic thorough cleaning of the grate, while in the electric locomotive there exists no comparative limitation.

The handling of the electric locomotive is also inherently different from that of a steam locomotive. Perhaps the most noticeable difference from the standpoint of the engine runner is the difficulty of accurately gauging the speed of the electric locomotive. The rhythm of the exhaust on the steam locomotive furnishes an excellent speed indicator to a trained ear, while there is nothing except passing objects from which to judge the speed of the electric locomotive. This has made it necessary on some high speed electric machines to install speedometers, and in some cases, instruments of the recording type are used to check the racing tendency of the engine runners.

COMPARISON OF DETAILS WITH STEAM LOCOMOTIVES

It will probably be interesting to note a few of the locomotive parts calling attention to differences existing between usual steam practice and, for instance, the New Haven electric passenger locomotives, giving reasons for the differences:—

Driving Wheels—The tires are the same in both classes of machines. The driving wheel centers of the electric locomotive are, however, entirely different from anything previously built, in order to accommodate the particularly flexible drive used on these machines.

Axles—The axles of electric machines differ from the usual American steam practice in that the journals are outside the driving wheels and the axles are tapered toward the center to gain clearance between the axle and the motor quills.

Driving Axle Boxes—These are in reality large motor car boxes adapted to the electric locomotive. The lubrication of these

bearings forms a difficult problem, as there is no pumping action to assist in distributing the lubricant, as is the case with a steam locomotive, and the resultant uniform pressure on the brasses maintains a constant location, instead of moving over a definite area with every revolution as with the steam locomotive.

Side Framing—The absence of reciprocating strains in the electric locomotive makes the use of light frames possible. (In a rigid frame electric locomotive, however, this is in some measure offset by the fact that there is very little strength in the superstructure.) On account of the absence of reciprocating strains in the electric locomotive, it is not necessary to provide wedges to take up the wear between the side frame and the journal boxes, as is always done on steam locomotives. The side frames in the New Haven electric passenger locomotive are made light in weight because they do not transmit the strains resulting from the bumping of the entire weight of the locomotive.

Cab Construction—The construction of the cab and its connection to the trucks is somewhat like a car problem, and steam locomotive experience is of small assistance. The proportions necessarily employed, however, are of necessity radically different from those occurring in any ordinary car.

This line of comparison could be carried out indefinitely, but enough has been given to show that throughout the entire detail of the electric locomotive there are requirements inherently different from those which have dictated the design of the modern steam locomotive. For this reason, the mind of the designer must be always on the alert to make sure that he does not copy from the steam locomotive, features of questionable merit in their application on an electric locomotive.

REDUCTION OF COST

In the present state of the art one of the problems of most vital importance is the reduction of the cost of all parts of the electric locomotive. To this end many suggestions have been offered. From the designing standpoint, there are only two possible lines of attack on the problem of cost reduction. One is the use of less material or cheaper material, and the other is the reduction of the labor involved. The use of plate steel and rolled steel shapes to replace cast steel offers an attractive field for investigation. The questionable feature of plate and angle structure is, of course, the reliability of the attachments. Frames of this type, however, are

largely used in England and France for steam locomotives and are carried to perhaps the highest degree of perfection in the electric locomotives manufactured by the Italian Westinghouse Company. In American steam locomotive practice the use of plate frames has met with small favor. There seems, however, to be room for a reasonable doubt as to whether the absence of the severe cranking strains of the steam locomotive may not remove the most serious obstacle now in the way of the successful operation of electric locomotives equipped with plate frames. In this connection, it is of interest to note that in the New Haven passenger locomotive the bumping and pulling strains are all transmitted through a plate and rolled shape structure, although the truck side frames are cast steel. There were some detail difficulties with the attachments in the early service of these locomotives. These were easily corrected, however, and the structure is now entirely successful in its operation.

DESIRED CHARACTERISTICS

The basis upon which the mechanical design of any locomotive rests is four-fold:—

First, there must be strength in all parts sufficient for the maximum service.

Second, the locomotive must be adaptable to the desired speed.

Third, it must suit the curves over which it is to operate.

Fourth, it must have wearing characteristics for continuous service, such as ample bearings, etc., to reduce the wear and tear to an operative amount.

The second factor involves many serious features and especially in the case of high speed locomotives, the widest range of opinion exists as to what general principles are essential. There seems to be a universal agreement that the "proper weight distribution" is essential to high speeding, but the definitions of the qualifying word "proper" are legion.

High Center of Gravity—From the performance of actual locomotives it seems reasonable to conclude that, other things being equal, the higher the center of gravity, within the limits of safe operation, the better will be the high speed tracking characteristics of the locomotives. It is not conservative, however, to assume that high center of gravity is the only method of attaining good tracking qualities. The essential feature is that the main mass of the

locomotive follow the general direction of the track, and that the minimum of mass follow the slight rail irregularities. Any feature tending to this end should receive most thorough consideration, and should be condemned only when it is evident that it involves features so serious as to overshadow the desirable qualities. High center of gravity has been singled out because up to date it seems to be the feature which has to the greatest extent been successful in actual service.

Double Ended Operation—This is also a serious complication in high speed running. Some designers claim that, since the locomotive must run as well in one direction as the other, it is a mere truism that both ends must be identical. Others hold that an unsymmetrical wheel base is essential to high speed operation. Certainly the modern high speed steam locomotive is unsymmetrical in respect to its wheel arrangement, but probably the performance of some of these machines in high speed backward operation would be about as good as that of an arrow shot feathers first. The New Haven electric passenger locomotives can be quoted as proving either point, for as the locomotives now stand they are very good high speed machines. The advocate of symmetry may point conclusively to the fact that both ends of the locomotive are identical, while his opponent with equal weight may argue that each truck is unsymmetrical in its wheel arrangement. Aside from all theorizing on the subject, the actual operation of electric locomotives has not proven the case in favor of either contention, and the argument will probably go on indefinitely.

Weight Equalization—The problem of weight equalization on the various wheels is closely associated with the choice of wheel arrangement. In high speed steam locomotives for single end operation a three point equalization, with one point leading and two points trailing, is almost universal. Any boy who has tried to ride his velocipede backward down hill knows the single point leading has decided advantages. Now it is obviously a mechanical impossibility to design a stable locomotive with a three point suspension with a single point on each end, as the three points must then be in a straight line. Thus we are face to face with one of three things:—First, running, so to speak, feathers to the front, part of the time; second, a departure from the three point suspension; third, some automatic method of modifying the suspension so that a single point will always lead with two points trailing. The plate steel frame seems again to

offer possibilities, because it can be made with some torsional flexibility, which will tend to justify a four point equalization. On the Continent many steam locomotives are made entirely without equalizing levers, the effect of equalization being secured by a rather flexible spring over each wheel which, together with the flexibility of the plate frames, seems to give a sufficient equalization. It should be noted, however, that the Continental practice is radically different from our American practice in many features. The wheel weights and the track construction vary greatly, while the inspection and adjustment of machines is followed very much more closely on the Continent than in this country. Some of the prominent American builders are advocating a departure from the three point suspension in the case of large rigid frame electric locomotives. No high speed machines of this type have as yet been built, however, which would demonstrate the wisdom of this departure. The burden of proof evidently rests on the four point suspension, as the steam locomotive has proven that a machine with a three point suspension and high center of gravity will run at high speed in one direction with a surprisingly small amount of injury to the track.

Diameter of Driving Wheels—The development of the steam locomotive has shown that as higher speeds were required it became necessary to increase the diameter of the driving wheels. This increase reduces the cost of maintaining both the rolling stock and the right of way. The increase in speed meant a corresponding increase in power with added weight and, therefore, greater wheel loads. To carry this load it was necessary to have either a greater contact area between the wheel and the rail, such as is secured by large drivers, or else to have better material in the rails and the tires. Eventually both improvements were adopted, and it should be noted that a continual research is in progress looking toward the production of still better materials. This saving of the track, however, was in a measure a secondary consideration as it seems to be impracticable to operate connecting rods at more than 400 revolutions per minute. The high piston speed involved in a greater number of revolutions also becomes troublesome. The rough and ready rule, at present in favor, is to design the driving wheels of steam locomotives for what is termed "inch diameter speed," which means a locomotive speed of a mile per hour for every inch diameter of the driving wheels.

There has been much argument regarding the comparative merits of large and small driving wheels for electric locomotives.

With geared or gearless concentric motors the objections which connecting rods offer to high speeds at once disappear. Small driving wheels of themselves impose upon the rails a less dead weight per axle, but due to the fact that, at a given speed of locomotive advance, a small wheel will climb onto a bad rail end or defective frog, much quicker than a large wheel, the vertical blow applied to the track is larger with the small wheel in comparison to its weight than it is with the larger wheel. Steam locomotive operating men seem to be quite unanimous in their preference for wheels having a diameter of not less than 56 inches for all kinds of heavy main line electric locomotives.

RELIABILITY

While the general question of maintenance which has been hinted at above is of great importance, yet far greater stress is to be laid on reliability and safety. A single illustration in this connection will suffice. It is well known that a steam locomotive crank pin lubricated with oil will have less wear per 100 locomotive miles than a grease lubricated pin. It is also a fact learned by hard experience that the best crank pin oil cup will occasionally fail to work, while a crank pin grease cup is practically perfect in its operation. For this reason, the grease cup is now widely used, the greater wear and maintenance involved being less objectionable than the occasional delays resulting when oil is used for lubrication.

The question of reliability has often been raised in connection with geared motors, the gear having been viewed with distrust. This feeling, however, is rapidly disappearing as a result of the fine gear performance on the St. Clair tunnel locomotives and other similar machines, as well as on interurban cars. So far as safety is concerned, it is unquestionable that a broken connecting rod or crank pin involves far more danger of loss of life than broken gear teeth. It must be stated, however, that it is possible to design side rods with a very great factor of safety, as was done in the case of the new Pennsylvania electric locomotives, so that the danger of such breakages as referred to above is practically eliminated, and in that design the use of connecting rods allows high center of gravity and renders the motor cleanly and accessible.

THE SCOTCH YOKE

The same effect of high center of gravity is gained, though in a much less degree, by the use of the Scotch yoke, as applied on the three-phase locomotives manufactured by the Italian Westing-

house Company. The great gain, however, in this Scotch yoke application is that it allows the use of two large motors in connection with three or more pairs of drivers of rather small diameter, the small diameter wheels meaning comparatively high motor revolutions. In the applications referred to the wheel weights and speeds involved are not excessive.

This arrangement seems to be peculiarly well adapted to three-phase installations because of the great gain in weight, cost and efficiency of the two large motors, as compared with four smaller motors of the same total power.

BRAKE RIGGING

One of the noticeable features in most discussions on the elecric locomotive is that no space is devoted to the mechanical means for stopping the locomotive. This is probably because there is so little difference in the brake rigging on steam and electric locomotives. Only one marked difference need be noted. A greater brake shoe pressure upon the tires is necessary in the electric locomotive than in the steam locomotive of the same weight, since in the steam locomotive most of the stored energy in the moving mass is energy of linear motion, there being only a small percentage of rotative energy stored in the wheels. But in the electric locomotive, especially if equipped with powerful geared motors with a large gear reduction, the energy of rotation is a surprisingly large percentage of the total energy stored in the moving mass, and the friction of the brake shoes on the tires must dissipate all of this stored energy.

SINGLE-PHASE INTERURBAN CAR EQUIPMENTS OF THE ROCK ISLAND & SOUTHERN RAILROAD

L. G. RILEY

ONE of the most recent applications of the single-phase system to interurban car service is to be found in the 52 miles of line of the Rock Island & Southern Railway Company between Rock Island and Monmouth, Illinois. The line is single track throughout, and for a distance of 20 miles from Rock Island follows the right of way of a branch of the Chicago, Rock Island & Pacific Railroad. The remaining distance of 32 miles is over a newly graded private right of way, which, as may be seen from Fig. 1, runs directly south in almost a straight line. Throughout its entire length, the line is exceptionally free from severe gra les and sharp curves.

At Monmouth, the southern terminal, where the car barns are located, direct connection is made to Galesburg over another division operated by the same company, a 500 volt direct-current line 18 miles in length. Rock Island, the northern terminal, is connected to Moline and Davenport by city and local service. Aledo and other intermediate points are reached by branches of the Chicago, Burlington & Quincy, and the Chicago, Rock Island & Pacific Railroad.

The power house is located close to a coal mine, at about the middle of the line. Two 1 000 k.v.a. turbo-generators furnish power at 2 300 volts, 25 cycles, single-phase, which is stepped up to 11 000 volts, and fed directly to the trolley wire at the power house. The single catenary trolley construction is used, consisting of a 4/0 copper wire suspended from a steel messenger cable. The drop in voltage at the end of the line under the worst conditions of load distribution is so small that no feeders are to be installed.

TYPES OF CARS USED

Since the new line is the only north and south road of any kind in that section of Illinois, arrangements are being made for handling passenger, express and freight traffic. The initial equipment consists of six passenger cars, one express and local freight car, and one slow speed freight locomotive for heavy through freight service.

PASSENGER CAR EQUIPMENTS

The passenger cars weigh 52.5 tons each, without load, and are 62 feet long over all. They will be operated under a two-hour headway, and are scheduled to make the single trip in two hours and 15 minutes. This schedule includes four regular stops and makes allowance for about one-third of the flag stops, which are located on an average of one mile apart. A schedule speed of 22 miles per hour is possible without exceeding a maximum speed of 40 miles per hour. As the available maximum speed is 45 miles per hour, there is a good margin for making up lost time.

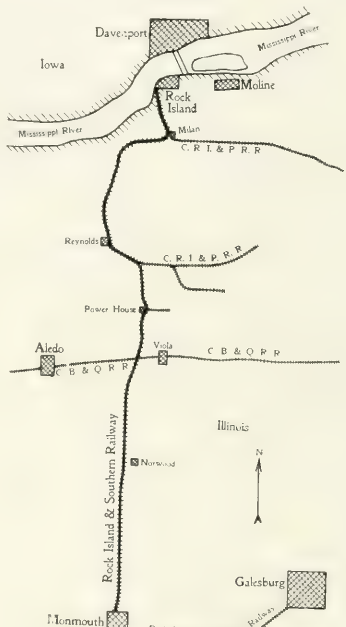


FIG. 1—MAP SHOWING ROCK ISLAND SOUTHERN RAILWAY AND CONNECTIONS

The electrical equipment consists of four 100 horse-power, single-phase motors, an oil-insulated, self-cooled auto-transformer, two 11 000 volt pneumatically-operated pantagraph trolleys, one 11 000 volt oil circuit breaker, three preventive coils, one group of 12 electro-pneumatically operated unit switches, a reverser, a 14 volt storage battery for the operation of the magnet valves, a motor-generator set for charging the battery, a speed limit relay, a barn contact plate and knife switch, two master controllers, and the necessary control circuit receptacles and jumpers for multiple unit train operation. With the exception of the speed limit relays and the motor-generator set, which are located in a bulkhead behind the motorman's compartment, and the trolleys and master controllers, all of the apparatus is suspended beneath the car body between the trucks. Compressed air is taken from the main reservoir and reduced to 70 pounds pressure for operating the various pieces of apparatus.

The motors are of the standard series, commutator type, with short-circuited auxiliary field windings. The motor gear is mounted

directly on the axle of the truck wheels which are 37 inches in diameter, and the motor frame is spring suspended from the truck bolster by a single nose in the ordinary manner. Eight taps giving different voltages are brought out from the auto-transformer for the acceleration and speed variation of the main motors. The air compressor and motor-generator set are each operated from separate additional low voltage taps. A small series transformer is connected to the high tension lead inside the auto-transformer and operates the overload trip mounted on the circuit breaker. A fuse of a few amperes capacity is connected in parallel with the tripping coil to

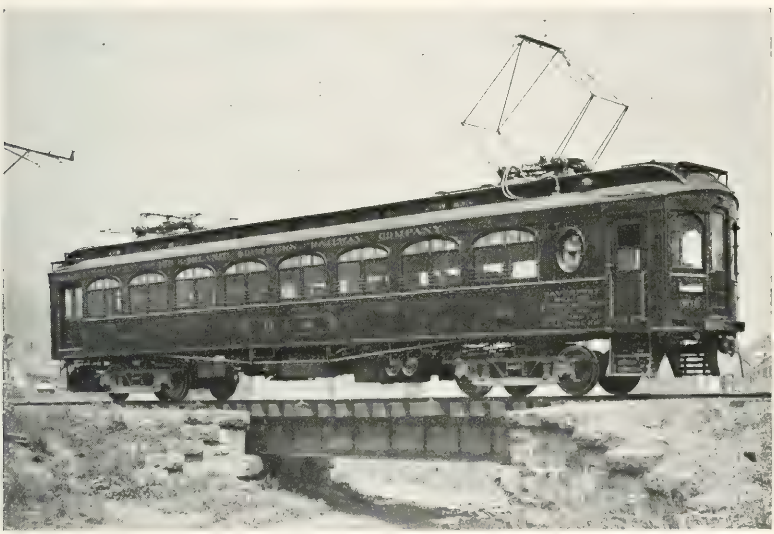
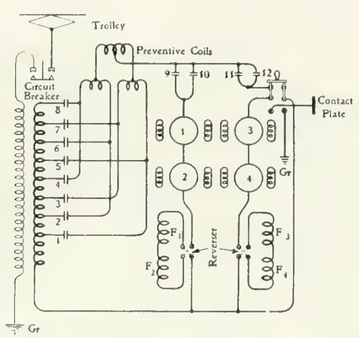


FIG. 2—ROCK ISLAND AND SOUTHERN PASSENGER CAR

prevent the circuit breaker from opening as a result of momentary surges in the high-tension lead, when the primary circuit of the auto-transformer is made or broken. The circuit breaker is closed by an air cylinder and opened by a spring when the control circuit to the magnet valve is broken. This circuit is connected through a removable contact plug in the master controller and a contact disc on the overload trip plunger. This plunger latches open when operated by an overload, and can be released only by removing the plug from the master controller and placing it in the "reset" hole, thus energizing the reset coil. The circuit breaker will then close when the plug is returned to the "cut out" hole.

Each of the 12 unit switches in the switch group is provided with a magnetic blow-out and is operated by air through magnet valves, in the same manner as the circuit breaker. The main circuit connections and the order in which the switches are closed for acceleration are shown in Fig. 3. The motors of each pair are connected permanently in series, and the impressed voltage from the auto-transformer is double that required for one motor; thus the amount of current to be handled by the switching apparatus is decreased as far as is practicable. From the auto-transformer four taps feed through two preventive coils, two taps to each coil, and the voltages are equalized at the middle point of each coil to an average between their values at the transformer. The voltage values from the respective preventive coils are equalized in a third preventive coil, and thus the resultant of the four taps is fed to



Sequence of Switches

Step	Switches											
1	1								9	10	11	12
	1	2							9	10	11	12
2	1	2	3						9	10	11	12
	1	2	3	4					9	10	11	12
3		2	3	4	5				9	10	11	12
4			3	4	5	6			9	10	11	12
5				4	5	6	7		9	10	11	12
6					5	6	7	8	9	10	11	12

FIG. 3—MAIN CIRCUIT WIRING DIAGRAM AND SEQUENCE OF SWITCHES

the motors through the main switches. Only two transformer switches are closed on the first notch, giving a low starting voltage which is not, like the other notches, intended for continuous operation. The impressed voltages on two motors in series varies from 210 volts on the second notch to 460 volts on the sixth or last notch. Each transformer switch is interlocked so that it cannot close unless the other switch attached to the same preventive coil lead is open, thus preventing any possibility of a short-circuit between the two taps.

The reverser, which changes the relation of the fields of each pair of motors with their armatures, consists of a contact block arranged to slide between the contact fingers connected to the motor leads. Two air cylinders with magnet valves serve to shift the contact block to either the forward or the reverse position.

Current for the control of all magnet valves is derived from a small 20 ampere-hour, seven cell storage battery, which is normally connected to the motor-generator set, but is capable of operating the car for 24 hours or longer on a single charge. The motor-generator set may be used indefinitely without the battery, so that there are two independent sources of control power available at all times.

Where long runs are made without stops on level track or on down grades, the cars may attain excessive speeds if full power is held on. To prevent damage to motor armatures from abnormal

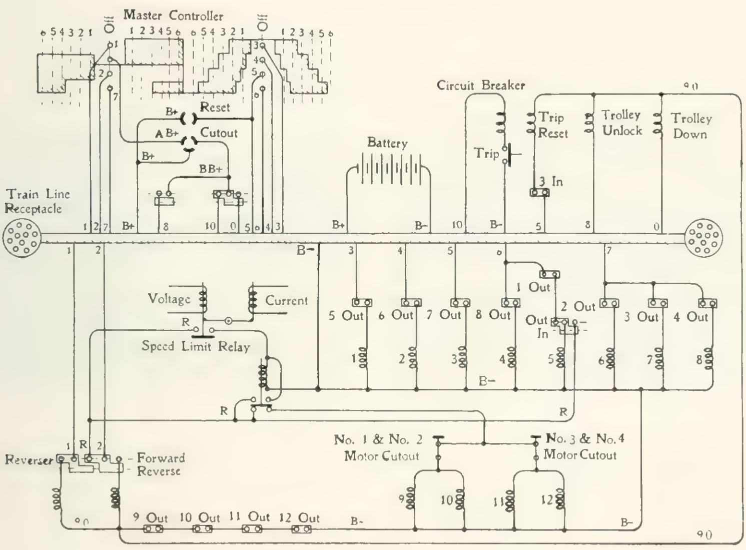


FIG. 4—CONTROL CIRCUIT DIAGRAM

peripheral speeds under these conditions, a relay is provided, which will remove power from the motors at a predetermined maximum safe speed. As indicated in Fig. 4, the relay consists of two coils, the cores of which are balanced by a rocker arm and carry a contact disc. One coil is energized through a series transformer by the current in a motor lead and the other by the voltage across one motor armature. The relay disc is normally held away from its contacts by the unbalanced weight of the two relay cores, but when the motor accelerates to such a speed that the voltage across the armature overbalances the decreasing current passing through the motor, the relay disc lifts, thus making a contact which serves to close the

control circuit of an auxiliary relay, which in turn lifts and opens the control circuit to the main motor switches. The auxiliary relay operates from the battery circuit and remains up until the master controller is returned to the off position.

The barn switch and contact plate, mentioned above, are provided for the purpose of shifting the cars in and out of the barns without the use of high-voltage overhead wiring. By placing the double-pole, double-throw knife switch in the opposite position from that shown in Fig. 3 and and applying a suitable low voltage from a flexible jumper to the contact plate, located in an accessible place under the side sill, one pair of motors are utilized in moving the car at low speed.

A master controller at each end of the car provides for continuous operation in either direction, although, under normal condi-

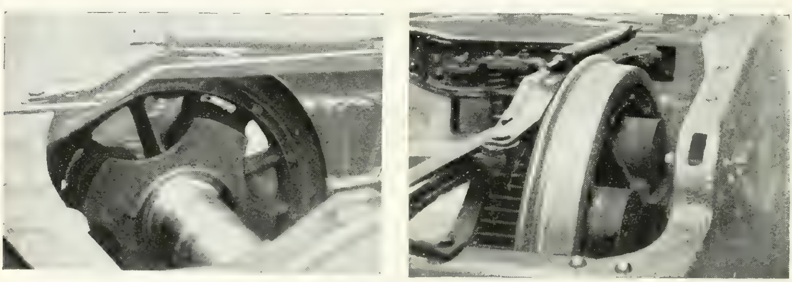


FIG. 5—DETAIL VIEW OF QUILL IN PLACE BEFORE MOTOR IS MOUNTED

Arrangement giving flexible drive and spring mounting for motor, thus preventing transmissal of vibration or sudden torque from armature to truck and car body.

tions, it is the intention to operate from the head end only. Each controller consists of a single drum to which is attached a detachable handle, which returns to the off position from any notch as soon as it is released by the operator. The two halves of the drum are duplicates, except for the connections to the reverser wires. Forward operation is secured by moving the drum to the right, and reverse operation by moving the drum to the left from the "off" position. The plug which makes contact for the circuit breaker also connects the battery circuit to the controller drum. This plug is attached to the handle by a chain and both are removed from the car when it is not in service.

The control circuit diagram, Fig. 4, shows the method by which multiple unit operation is secured by means of 12 train line control wires. The four main motor switches are closed by current

through the reverser wire, which is transferred to the *R* wire (Fig. 4) by the reverser interlock, after the reverser has been thrown to the proper position, getting its circuit to *B*— through the interlocks on the main motor switches in the "out" (open) position. This mutual interlocking prevents the reverser from being thrown while power is being supplied to the motors, and prevents the switches from closing until the reverser in is the position desired by the operator. The positive and negative battery wires, two wires for the reverser, two for handling the pantagraph trolleys, and one for the circuit breaker, leave five wires for manipulating eight transformer switches and resetting the circuit breaker. Reference to the diagram, Fig. 4, shows that the first four transformer switches are closed individually by means of as many wires. The control circuit of the fifth switch is connected to the same wire as that of the fourth switch through the interlock contact of the first

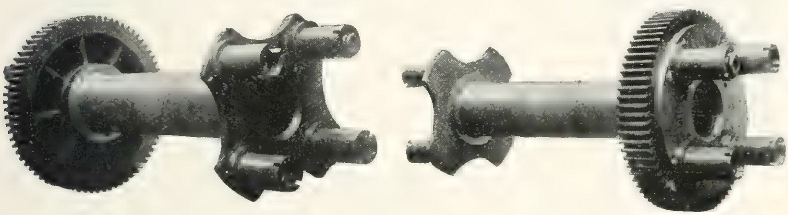


FIG. 6—TWO VIEWS OF MOTOR QUILL USED WITH FLEXIBLE DRIVE ON EXPRESS CAR AND FREIGHT LOCOMOTIVE

switch open, and is held by means of the *R* wire, because the wire that serves to complete the circuit by which the fourth switch is held in must be broken to produce the last notch. The sixth switch is closed by means of the one remaining wire, through the second switch in its open position, and the seventh and eighth switches are brought in, like the fifth, by opening the respective switches with which they are interlocked. Thus it is seen that the safety interlocking arrangement, mentioned in connection with the transformer circuits serves a double purpose. One of these wires is utilized for resetting the circuit breaker by an interlock circuit through its own transformer switch closed, and through the main switches open. The interlock on the third switch is necessary to obviate the possibility of energizing the circuit breaker reset coil through the main switch interlocks before these switches close, a condition which would otherwise occur in case the controller were moved quickly from the off to the second position.

Push buttons in the master controller manipulate the pantagraph trolley, and the one which lowers the trolley also opens the circuit breaker so that no arc can be drawn between the trolley wire and contact shoe, when the trolley is lowered.

EXPRESS AND FREIGHT EQUIPMENTS

Express and local freight service is to be handled by a car geared for the same schedule speed as the passenger cars. At times this car will haul one or two standard freight cars, and when making the same number of stops as the passenger cars the time for a single trip will be two hours and 40 minutes. On holidays or on days when passenger traffic is heavy this car will be used as a locomotive with four or five standard passenger coaches, making regular stops only.

FIG. 7—QUILL SPRING

Through freight service will consist mainly in hauling coal from a mine near the power house to Rock Island and Monmouth without stops, except for turn-outs. The freight locomotive is to be the same size and is to have the same equipment as the express car, but will be geared for low speed. It will be capable of hauling a trailing load of 300 tons in loaded cars over the entire line. The tractive effort available for starting loads is above 25 000 pounds.

METHOD OF MOTOR DRIVE AND SUSPENSION

Both of the heavy cars are equipped with four 125 horse-power motors, which have forced ventilation and are provided with flexible drive between the motor gear and the wheel. In other respects the equipment is the same as that of the motor cars, except that additional capacity has been provided in all main circuit apparatus, because of the larger motors used.

Flexible suspension and flexible drive are used with single-phase motors of this size to prevent the vibration which occurs at low speeds and heavy loads from being transmitted to the truck frame and car body. The manner in which flexible drive is secured is illustrated in Fig. 5, which shows two views of the truck ready to receive the motor. The motor gear is integral with a hollow quill, two views of which are shown in Fig. 6. The quill

has a bore considerably larger than the diameter of the truck axle and is put in place before the second wheel is pressed on.

The four pins in the end of the quill enter pockets in the wheel hubs, and each one is there supported by a heavy helical spring wound eccentrically from square stock, as shown in Fig. 7. The spring is assembled under lateral compression, with an inner and an outer sleeve, as shown in Fig. 8, and forced into the pocket and around the quill pin, thus separating the pin from the wall of the

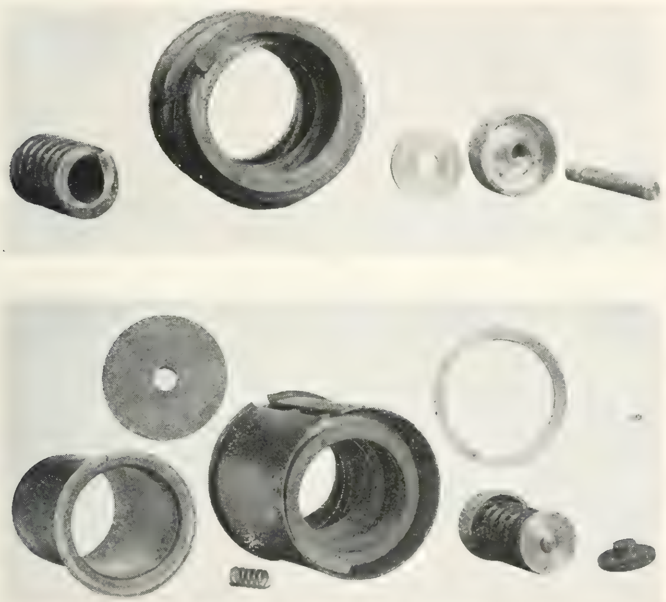


FIG. 8—FLEXIBLE DRIVE DETAILS, SEPARATE AND PARTIALLY ASSEMBLED

pocket. Under load the pin may be forced towards one side of the pocket or the other, and the spring assumes the shape of the ordinary helical spring. As the spring is always under stress, it absorbs the greater part of the vibration which originates in the motor. A smaller spring, also shown in Fig. 8, is placed inside the quill pins and is compressed by the cover plates which are screwed into the hub pockets, as shown in Fig. 5, to keep the flexible drive details in place. This spring is separated from the pocket cover by a wearing plate and the two together take care of the

end thrust of the quill. The middle portion of the quill forms journals for the motor axle bearings, and the weight of the motor is divided between the quill and the motor nose, which is spring suspended from the truck bolster.

CONCLUSION

Conditions more favorable to the success of an interurban road, both from a financial and an operating standpoint, could hardly be imagined. Practically no direct competition exists, and the variety of service offered should meet with a ready response, especially in view of the fact that only indirect steam service has heretofore been available in this district. The essential features of the equipments have all been in use on other roads for a sufficient length of time to have proven themselves entirely satisfactory, while the minor details have been laid out so as to take full advantage of the very latest improvements. This, together with the extreme simplicity of the equipments, insures good service with a minimum expense for inspection and maintenance.

A PHOTOGRAPHIC RECORDING METER

L. M. ASPINWALL

IN making tests on electric locomotives and cars it is necessary to have a complete set of current, voltage, power and speed readings, in order to determine accurately the performance of the equipments. The necessary readings are usually obtained by having a number of "observers" on the locomotive to read portable instruments simultaneously at equal predetermined time intervals. This method is more or less costly and is open to the objection that considerable error is likely to be introduced on account of the "personal equation" of the various observers. Anyone who has had occasion to make tests of this character realizes the desirability of having some form of instrument which will graphically

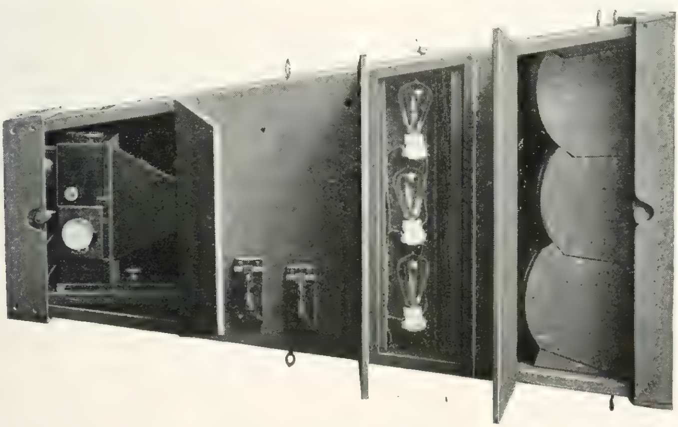


FIG. I—PHOTOGRAPHIC RECORDING METER
Showing parts mounted in case.

plot the speed, voltage, current, time and other readings which are required, thus eliminating the personal error and reducing the cost of making such tests to a minimum.

The writer has for a number of years past been connected with work which calls for a considerable amount of such testing and has consequently given the matter of an instrument of this character considerable thought. The use of a kinetoscope type of camera which would photograph a number of indicating instruments at the rate of one or more exposures per second has been suggested at various times. Such an arrangement offers many advantages over the usual method of individual observers, but does not by any

means give the ideal arrangement. In thinking over this method several years ago, it occurred to the writer that, if edgewise indicating instruments (i. e., instruments with the pointers moving in a vertical plane), were used with a black scale and white divisions and pointer, they could be photographed on a film moving at a constant rate of speed at right angles to the meter, and that the white divisions would trace horizontal coördinates and the white pointer would trace a continuous curve, thus giving a finished record at one operation. This scheme looked so promising that with the assistance of Mr. Graham Bright (who aided throughout with valuable suggestions and furnished the camera for this occasion,) some preliminary tests were made which indicated that the scheme was perfectly practical. The next step was to design and build a special form of camera, which could be used in connection with commercial edgewise instruments, together with a special retaining case for holding the instruments and camera in proper relation. Edgewise meters with special dials and pointers were used for the indicating instruments. These meters were mounted one above another in a shallow case, and a shelf provided at one end of the case for the special camera, the arrangement being such that the camera lens formed the center of a segment of a circle, about whose circumference the meters were mounted, as shown in Fig. 1.

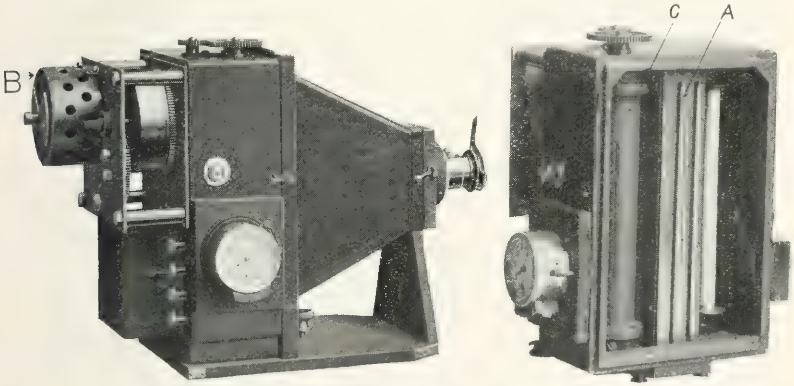
FIG. 2—VOLT-METER
Showing white scale figures and aluminum pointer.

The meters were all provided with dull black faces and the graduations consisted of short white lines, the scale figures being put on in white at one side, as shown in Fig. 2. Each pointer was provided on the end with a very small hemispherical polished aluminum piece, which always reflects a clear, bright spot from the source of light, and gives a good record on the film. The faces of the meters were illuminated by means of three 20 volt incandescent lamps set at one side out of range of the camera lens.

The camera was of the box type, as shown in Fig. 3, with a sliding lens for focusing. The film holder used is shown in Figs. 3 and 4. The clockwork attachment on the back is for the purpose of driving the roll *C*, on which the film is wound after passing over the platen *A* (Fig. 4), which is located in the center of the holder. The speed of the clockwork is regulated by a small centrifugal fan

B, the supply of air to which can be varied at will. The speed of the film is generally set at about 15 seconds per inch, but as a time record is also made on the film, it is not absolutely essential that its speed be perfectly constant.

The time record is obtained as follows:—The platen *A,* over which the film passes, is really a hollow box in which are mounted four miniature incandescent lamps. The front of the box is made of a brass plate in which is a very narrow slot extending the whole length of the box and located directly over the incandescent lamps. The lamps are so wired in connection with a small clock and relay that they give a quick flash every five seconds, and the light is projected through the slot in the platen on to the film, thus producing a sharply defined vertical line at intervals corresponding



FIGS. 3 AND 4—DETAILS OF CAMERA
A—Platen. *B*—Fan. *C*—Film roll.

to five seconds, when the film is developed. Inside of the camera, directly in front of the roll holder is a thin partition, which has a small slot in the center so that only the images of the pointers and the scale divisions are allowed to reach the film, the image of the scale figures being blocked off by the partition.

The camera is mounted on a pivot which allows it to swing through a short arc between two stops. When the camera is swung over to one of these stops, the images of the scale figures are thrown past the edge of the partition above mentioned and fall on the film. Before starting a test an exposure is first made with the camera in this position and the film at rest, this gives a record of the scale values and the camera is then swung back to the position where the partition hides the numerals, and the test started.

In making a record after the apparatus has been set up it is only necessary to close the circuits to the various instruments, switch on the lights and start the clockwork mechanism. Every motion of the moving pointers is faithfully recorded on the film, the scale divisions rule the horizontal coördinates, and the lights in the platen box flash vertical coördinates every five seconds as the test proceeds, so that when the film is developed a continuous record of the values desired is obtained. Figs. 5 and 6 show two records taken with this instrument.

Fig. 5 was taken with three meters in operation recording volts, amperes and speed on a 157 ton direct-current electric locomotive operating without load. The speed was recorded by a voltmeter

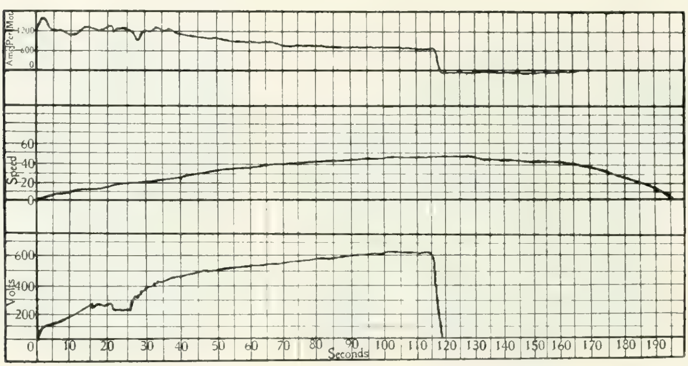


FIG. 5—CURVES TRACED FROM PHOTOGRAPHIC METER RECORD
Test on direct-current locomotive running light. Three meters.

connected to a magneto generator driven from the locomotive wheels and suitably calibrated.

The record shown in Fig. 6 was taken with four meters on an 86 ton single-phase car equipped with unit-switch control and automatic acceleration. It will be noted from this curve how every little variation of current and voltage is recorded. With the ordinary method of taking readings by observations made every five seconds, all of the variations between these points are lost and only an average reading can be made.

With the instrument above described the current for operating the lights for illuminating the scale and for the time flash is supplied by means of a small storage battery; this, however, is not absolutely essential, as the time flash can be operated by a few dry

cells, and the scale lights from the main supply circuit which is being tested. The instrument is not intended for commercial use, but merely as a useful adjunct for making special tests of the character described.

The setting up of the instrument and making the necessary connections require some little time, but after the apparatus is once mounted in the car or locomotive a number of tests can be run off

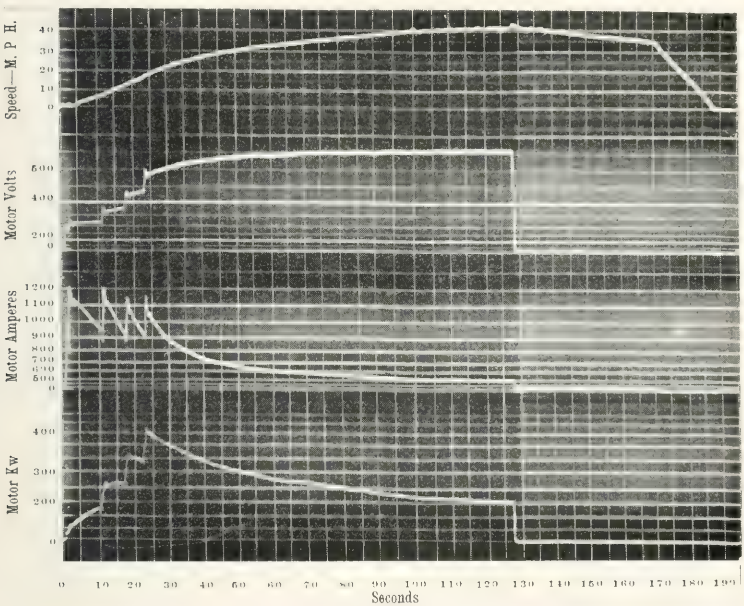


FIG. 6—SECTION OF PHOTOGRAPHIC METER RECORD

Taken in connection with test on 86-ton single-phase car. Four meters.

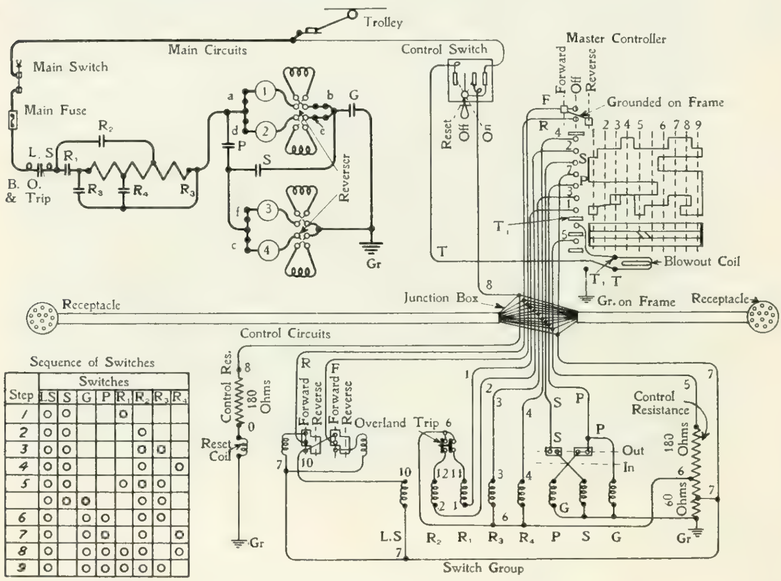
with a surprisingly small amount of effort on the part of the operator.

It is, of course, quite evident that the only limit to the number of instruments which can be photographed is the size and weight of the apparatus. The outfit which was used for making the test shown in Fig. 5 weighs approximately 125 pounds, including meters, camera and case, and occupies a space about five feet long, by three feet high, by one foot wide.

HAND OPERATED UNIT SWITCH CONTROL

KARL A. SIMMON

ONE of the recent developments of interest in the railway field is the hand operated type of multiple unit control. These equipments are noteworthy from the fact that while retaining all of the essential features of previous multiple unit control equipments, they have been so simplified that they can to advantage be used on cars heretofore considered too small for what has heretofore been a rather elaborate and expensive



Step	Switches							
	LS	S	G	P	R_1	R_2	R_3	R_4
1	o	o			o			
2	o	o				o		
3	o	o				o	o	
4	o	o				o		o
5	o	o			o	o	o	
	o	o	o			o	o	
6	o		o	o		o	o	
7	o		o	o		o		o
8	o		o	o	o	o		o
9	o		o	o	o	o	o	

FIG. I—DIAGRAM OF CONNECTIONS FOR QUADRUPLE EQUIPMENT OF 75 HP MOTORS OR LESS

equipment. Power operated control apparatus permits multiple operation of two or more cars and is of especial advantage in the case of single track, interurban roads, hauling large crowds during certain rush hours, as trains of two or more cars can be operated at a slight increase over the cost of single car trains without hampering the train dispatching and without increasing the possibility of accident. Multiple-unit operation often permits the operation of smaller cars with lighter equipment than would be possible if single car operation were adhered to throughout the

entire day, thus decreasing the cost of rolling stock as well as the cost of maintenance.

Various operating companies have taken many precautions in order to protect their passengers from injuries due to equipment failures. Some have absolutely prohibited passengers from riding near the controllers, especially on open summer cars where front seats are usually at a premium. Even where this is done, controller blow-outs or the opening of the circuit breaker have sometimes caused serious accidents, which resulted in well-founded damage claims. The use of power operated control equipments permits the location of all main circuit opening and closing devices beneath the floor of the car, where they cannot injure or alarm passengers. Moreover, apparatus of more liberal design may be employed, since

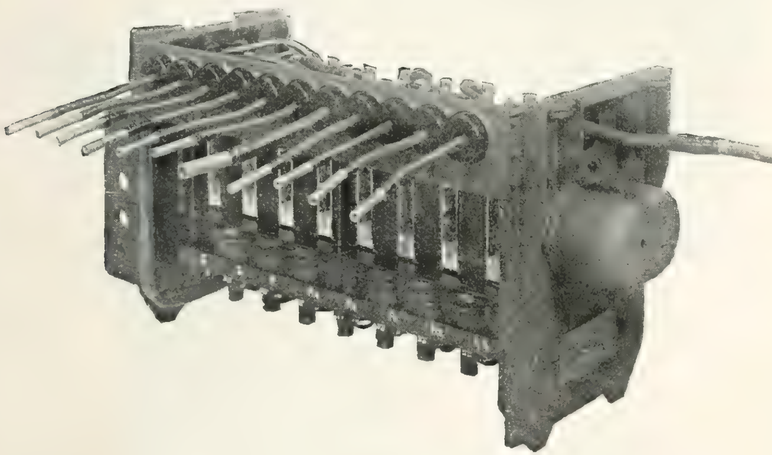


FIG. 2—UNIT SWITCH GROUP WITH COVERS REMOVED
Front View

the space beneath the car floor is not at such a premium as that above; thus liability to accidents is reduced and the life and efficiency of the equipments is increased.

APPLICABILITY

The hand operated type of unit switch control has been especially designed for service where apparatus of a simple character is particularly desired. On this account, various features, such as automatic acceleration, bridging transition, etc., which have heretofore been common to most power-operated control equipments, have been omitted. These features are not essential for the classes of service for which the equipments are intended and particularly where simplicity of parts is desirable.

DETAILS OF OPERATION

The main circuit connections between the trolley and the motors which are ordinarily made by means of a manually operated circuit breaker and a drum controller, are made, in the case of hand operated unit switch control equipments, by electro- pneumatically operated switches, each of which is provided with a powerful magnetic blow-out. The number of switches per equipment is, of course, dependent upon the motor capacity. In the case of the smaller hand operated equipments, six switches are used, and in the case of the largest equipments, a total of only ten switches is

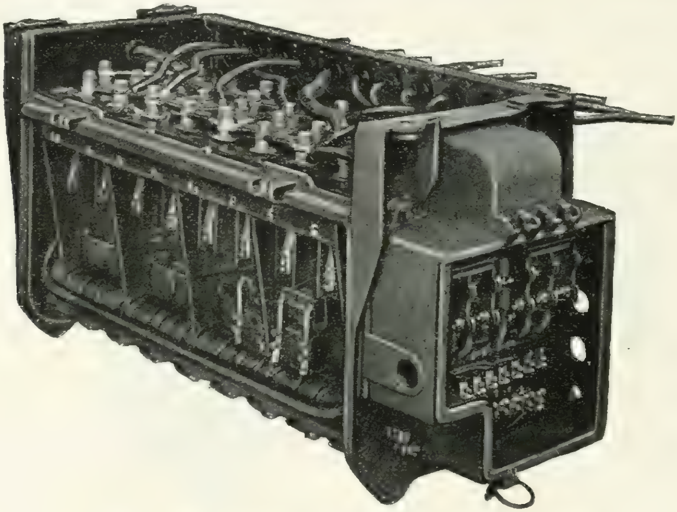


FIG. 3—UNIT SWITCH GROUP WITH COVERS REMOVED
Rear view.

required. In equipments, where six or eight switches are employed, they are all mounted in one frame termed a "switch group." For the largest equipments, where ten switches are used, eight of these are mounted in one group, while the two additional switches are assembled in a separate frame, termed a "line switch." Each of the individual switches is normally held open by a spring, and closed, when desired, by compressed air, which is admitted to the actuating cylinder by a magnet valve.

Method of Reversing—The changes in the main circuit connections required to effect a forward or a backward movement of the car, which are ordinarily made by the reversing drum of a hand controller, are made, with multiple unit operation, by a "re-

verser," consisting of a similar drum mounted in a separate cast iron frame and operated by a pair of pneumatic cylinders. The admission or release of air to and from the cylinders of the switches and the reverser is controlled by small magnet valves. The magnet coils of these valves are energized in accordance with a predetermined sequence through leads connected to a control "train line," which in turn is connected to the master controller. Upon moving the main handle of the master controller step by step, in a manner similar to that in which an ordinary hand controller is manipulated,

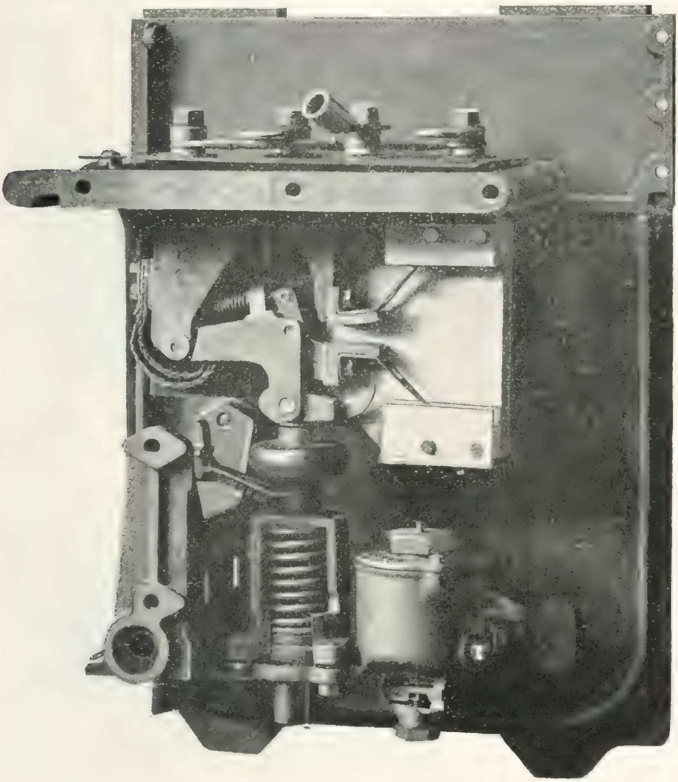


FIG. 4—UNIT SWITCH COMPLETE WITH OPERATING MECHANISM
Sectional view.

a "control resistance" is connected from the trolley to ground, thus energizing certain valve magnets which are connected through the controller drum to a low voltage tap on the resistance.

Multiple Operation—In order to provide for multiple operation of cars this control train line is carried throughout the length of the car and connected to train line receptacles at either end. By means of "train line jumpers" the control train lines of several

cars may be connected together, and thus the respective master controllers are all connected in multiple. The electro-pneumatic switches of each car can then be operated simultaneously from any master controller.

APPARATUS COMPRISING EQUIPMENT

In addition to the motors and motor details a hand operated control equipment, with complete apparatus for double end operation, includes the following items:—One or two trolleys, a main switch; a main fuse box; a switch group; a line switch (this is only used with large equipments); two master controllers; two control switches; three train line junction boxes; two train line receptacles; a train line jumper; a control resistance; a set of pneumatic details; one set of insulating details, and cable for control and main circuits.

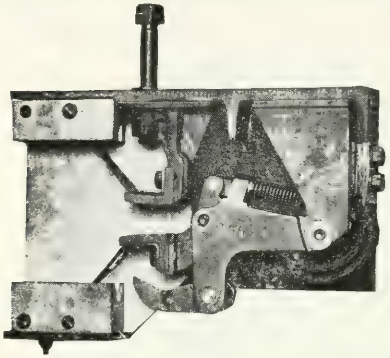


FIG. 5—UNIT SWITCH WITH SIDE OF INSULATING BOX REMOVED

ELECTRICAL CONNECTIONS

The general scheme of connections of the main and control circuits for aquadruple equipment of motors of 75 horse-power or less is shown in Fig. 1. An inspection of this diagram demonstrates the simplicity of this equipment which is due partially to the method employed in changing from series to parallel, partially to the ingenious scheme of the resistance connections, which permit a large number of steps with but comparatively few switches, and partially to the type of unit switch employed.

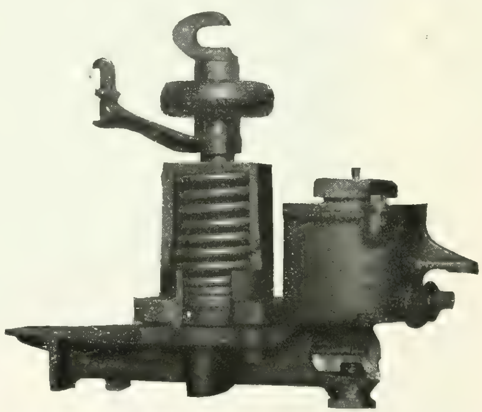


FIG. 6—CYLINDER AND MAGNET VALVE OPERATING UNIT SWITCH

A main circuit cut-out is mounted on the end of the switch group which enables the operator to cut out a pair of motors in case of a ground or similar trouble and still obtain series-

parallel operation, using one motor on one truck and one on the other as a pair. This results in smooth acceleration even in the case of a partially disabled equipment.

ELECTRICAL AND MECHANICAL DETAILS

Unit Switches—The type of switch group employed for quadruple equipments of 75 horse-power motors or less is shown in Figs. 2 and 3. It consists of eight independent or "unit" switches assembled in a frame, and protected by removable covers. Between the switches are copper strap coils which provide a strong magnetic blow-out. The detail construction of a unit switch is shown in Figs. 4 and 5. The switch consists of two copper alloy castings, one of which carries the upper or fixed contact, while the lower or movable contact is securely fastened to the other. All electrically charged parts of the switch are enclosed in an insulating switch box. Inside of the switch box and adjacent to the switch jaws a non-combustible arcing box is placed, which is readily removable in case it has to be replaced.

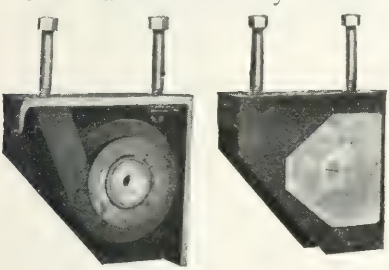


FIG. 7—BLOWOUT COILS USED WITH UNIT SWITCH

Air Cylinder and Magnet Valves—The air cylinder and magnet valve for operating the switch may be seen in Figs. 4 and 6. The cylinder details are shown in Fig. 6. It will be noted that the switch is normally held open by a powerful spring and is closed by compressed air. In this way, forces of over 100 pounds are available for both opening and closing the contacts. When the switches are closed there is a wiping action between the movable and stationary jaws, which materially assists in keeping the contacts in good condition. As the magnet coils operating the switches merely control the admission or release of the compressed air, the pressure on the switch jaws is entirely independent of the trolley voltage.

Overload Trip—In addition to the overload protection obtained by the main fuse, there is mounted in one end of the switch group an overload trip. This trip, which is located in the center of one of the blow-out coils, consists of an iron plunger encased in a brass tube and normally held in place by a spring. A rod carrying two insulated contact discs is attached to the iron plunger. When the plunger is in its normal position, as shown at *6* in the wiring diagram, Fig. 1, the valve magnet circuits of certain switches are

closed, provided the controller is in a running position. If, for any reason, the current in the main circuit should reach an excessive value, the iron plunger is drawn toward the center of the blow-out coil, moving the contact disc and thus opening certain unit switches. As soon as the overload trip has opened the cir-

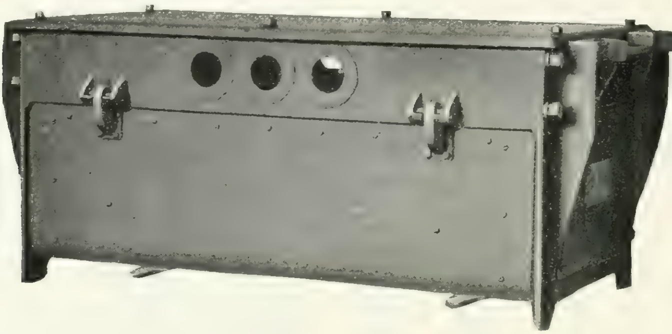


FIG. 8—FOUR-MOTOR REVERSER
Exterior view.

cuits made by the contact disc, it is prevented from returning to its normal position by a small locking device. In order to release the plunger, it is necessary for the operator to energize a "reset coil," which serves to release this locking device. These reset connections are shown in the diagram.

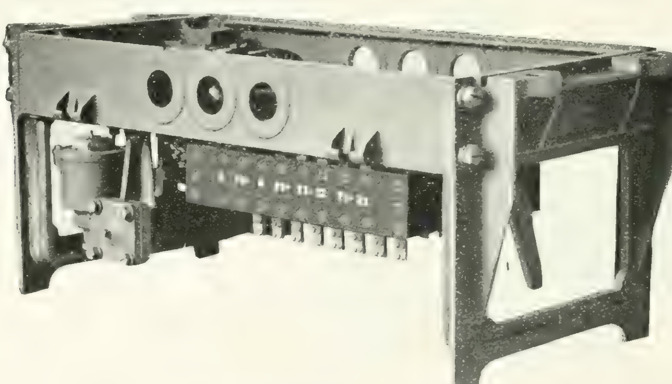


FIG. 9—FOUR-MOTOR REVERSER
Covers Removed.

Connections—The main circuit connections between switches and blow-out coils are made of copper straps connected to the various terminals with heavy copper bolts. The control circuit connections are led to a junction box mounted at one end of the group so that they are readily accessible and yet are protected from brake shoe dust or dirt.

Line Switch—The line switch which is used with the larger equipments is similar in all its details to a switch group, except that it contains but two switches instead of eght. When a line switch is included in an equipment, the overload trip mechanism is mounted on the line switch instead of on the switch group, its function being identical in the two cases.

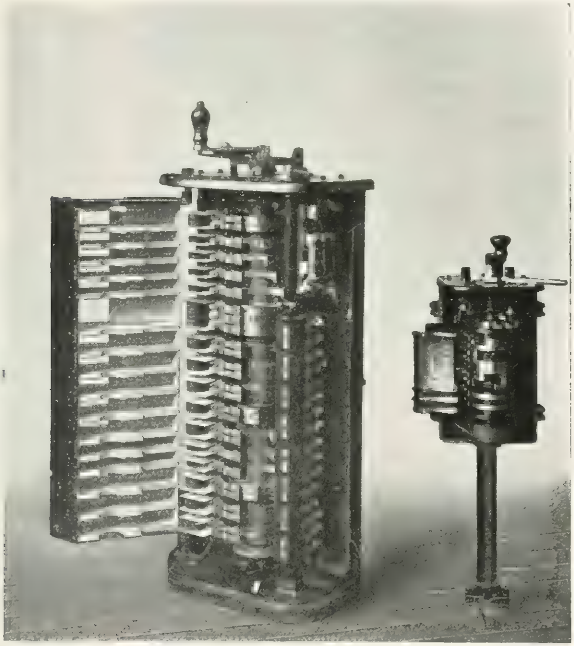


FIG. 10—HAND AND UNIT SWITCH CONTROLLERS FOR A QUADRUPLE EQUIPMENT OF 75 HP MOTORS
Showing economy of platform space in the case of multiple unit control.

Reverser—As stated above, the reversers employed with these equipments are similar in general to the reverse drum found in hand controllers, except that they are pneumatically operated, and much heavier pressures are employed on the drum contacts.

A set of interlock contacts is mounted on the reverse drum which prohibits false operation of the control. Exterior and interior views of a typical four-motor reverser are shown in Figs. 8 and 9. This particular type is used where the main wiring is installed in conduit.

Master Controllers—The interior of a master controller is

shown in Fig. 10. For all except the smallest equipments this controller has five series and four parallel notches. Like the ordinary hand controller, it has a power and a reverse handle which are mutually interlocked. This figure gives a comparative idea of the relative sizes of hand and unit switch controllers for a quadruple equipment of 75 horse-power motors.

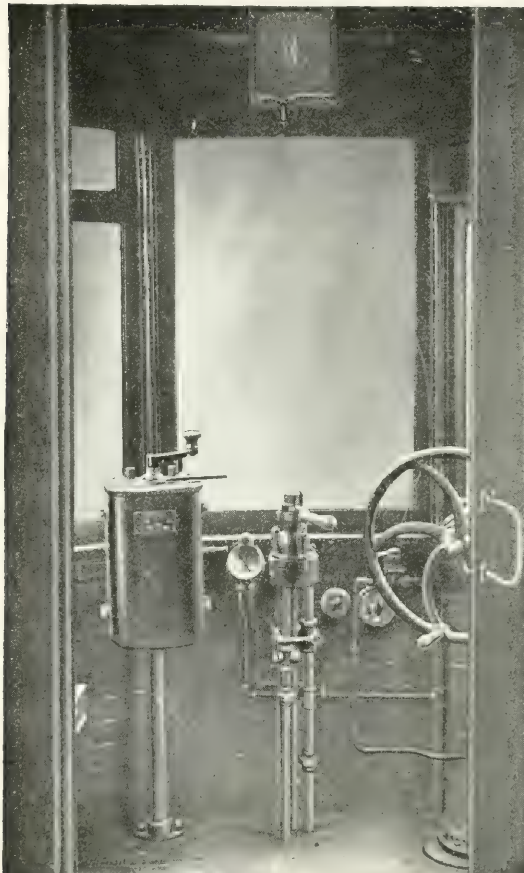


FIG. 11—UNIT SWITCH MASTER CONTROLLER MOUNTED ON CAR PLATFORM
Showing space economy.

Of late there has been a great tendency toward using "Pay-as-you-enter" cars for city service. This necessitates large platforms and, as the controller must be mounted at the extreme end of the platform where, owing to the great overhang, it is most desirable to have no more weight than is absolutely necessary, a small controller is of no mean advantage. A unit switch controller mounted on a car platform is shown in Fig. 11; this gives a further indication of the platform space economy effected by the use of unit switch control.

Control Switch—The control switch shown in Fig. 12 serves the dual purpose of a control cut-out and a reset switch. Referring again to the wiring diagram, Fig. 1, it will be noted that power

for the operation of the magnet valves comes through the control switch, so that it is essential that the control switch at the end of the car from which it is being operated must be in the "on" position. In case operation of the overload trip has occurred, due possibly to an attempt to accelerate too quickly, the operator must then return the master controller to the "off" position, and momentarily hold the control switch in the "reset" position in order to reset the overload trip as explained above.

Main Switch—A main switch is connected between the trolleys and the fuse box. This is to permit operation of the control during inspection without moving the car; it also permits the installation of new fuses without the necessity of pulling down the trolley. This is of considerable value when operating after dark, as with this arrangement it is unnecessary to put out the car lights when installing a new fuse.

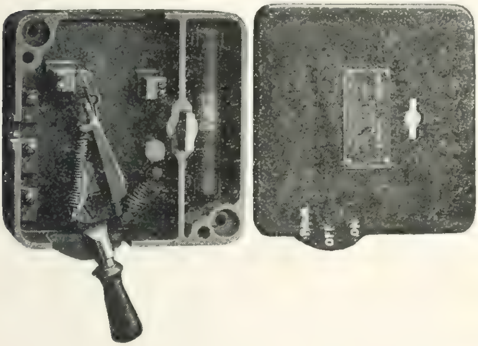


FIG. 12—CONTROL SWITCH

Compressed Air System—The pneumatic connections for a standard hand operated type multiple-unit equipment are shown in Fig. 13. The pneumatic parts consist of the necessary valves, a strainer and a reservoir. In some cases, where local conditions warrant the extra precaution, the control air piping is arranged in accordance with Fig. 14. This arrangement includes an "emergency control reservoir," which is always charged with air at main reservoir pressure through the "governor" or check valve. For regular operation the air passes direct from the strainer to the reducing valve through the three-way valve. In case of accident to the main air supply, the three-way valve is thrown through an angle of 90 degrees, thereby connecting the emergency control reservoir direct to the control through the reducing valve. As the amount of air used per acceleration is small, the air stored in the emergency control reservoir is usually ample to return the car to the barn under its own power.

Use of Conduit—The control wiring is usually installed in iron

conduit, as shown in Fig. 15. As there are comparatively few control wires between the various pieces of apparatus, the conduit sizes are small. To further simplify the installation of this conduit, suitable junction boxes with compact terminal boards are

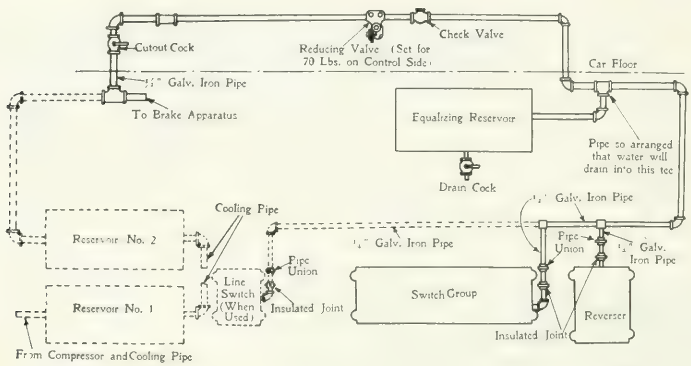


FIG. 13—STANDARD PIPING DIAGRAM
Unit switch control.

used. When once installed in this manner, there is little danger of trouble with the control circuits. The main wiring may or may not be installed in conduit, as desired. The method of bringing out

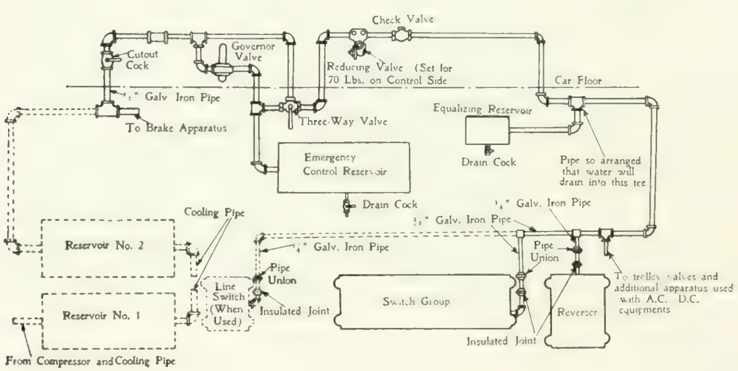


FIG. 14—PIPING DIAGRAM WITH EMERGENCY RESERVOIR
Unit switch control.

leads and the general arrangement of the apparatus, as shown in Fig. 16, is such that the main wiring may be put in conduit at a reasonably low cost. During the last few years, it has been the

practice of a large number of electric railway companies to place all the car wiring in conduit, as they find that the depreciation and

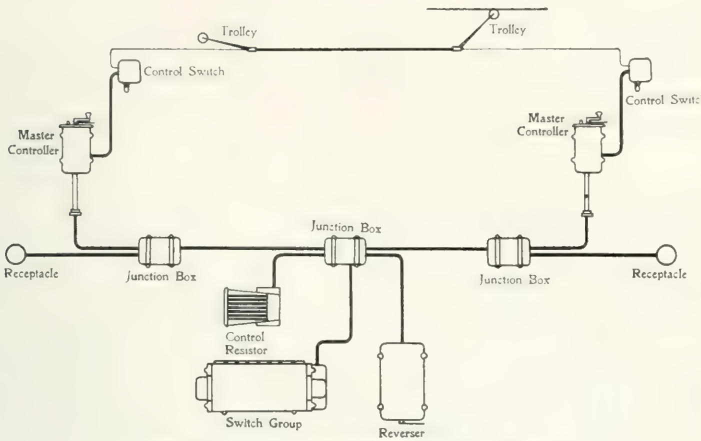


FIG. 15—DIAGRAM OF CONTROL CONDUITS

maintenance are decreased and the possibility of delays materially lessened. In addition to this there is also a considerable saving in the cost of fire insurance, as a lower insurance rate can usually

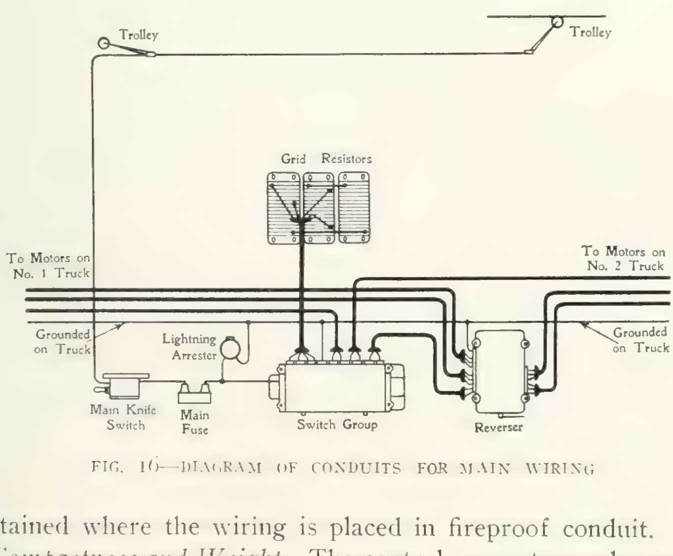


FIG. 16—DIAGRAM OF CONDUITS FOR MAIN WIRING

be obtained where the wiring is placed in fireproof conduit.

Compactness and Weight—The control apparatus under present

consideration is especially compact and light in weight. The small amount of space required is evident from the sample car layout drawing given in Fig. 17, showing an equipment capable of handling four 75 horse-power motors on a car with but 19 feet, six inches between truck centers, the distance between the truck clearance lines being only nine feet, three inches.

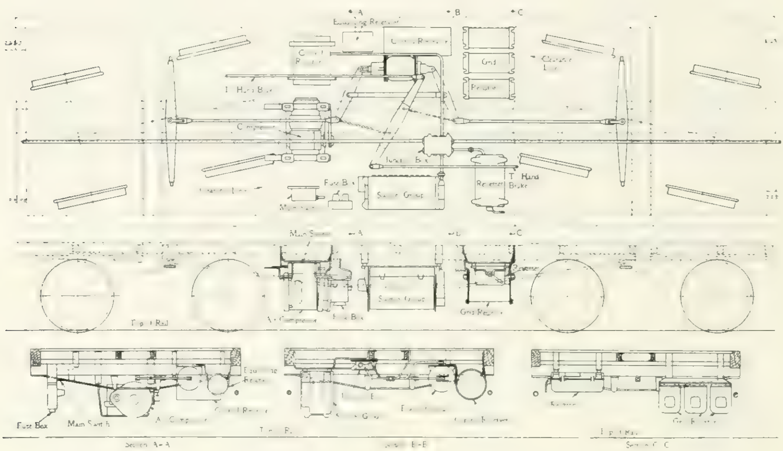


FIG. 17—CAR LAYOUT SHOWING ARRANGEMENT OF APPARATUS FOR A QUADRUPLE 75 HP EQUIPMENT

CONCLUSIONS

The general advantages of power operated control apparatus as compared to drum type controllers have already been touched upon. In addition to these, equipments of this type have many inherent advantages. Some of these may be briefly summarized as follows: 1—Multiple unit operation; 2—all main circuit interrupting devices are mounted beneath the car floor, away from the passengers; 3—the switches are liberally designed and are operated with heavy contact pressure; 4—platform space economy is effected; 5—the operation of switches is independent of line voltage over the entire operating range; 6—reliable overload protection is provided; 7—simplicity, reliability, and low maintenance costs are effected.

Although these equipments have been developed but a short time, there are a large number in use. These are handling both large and small motors in many kinds of service. In view of the

many advantages of this type of control and the exceptionally fine showing which has been made in service, it seems highly probable

FIG. 18—TWO-CAR TRAIN, FAIRMOUNT & CLARKSBURG TRACTION COMPANY
Equipped with four 50 hp interpole motors and hand operated unit switch control.

that their use will be rapidly extended, even to sizes of equipments heretofore considered too small to warrant the use of multiple-unit control.

WINDING OF DYNAMO-ELECTRIC MACHINES—V

DIRECT-CURRENT RAILWAY TYPE MOTORS

RAILWAY and mill motors are designed for essentially similar service. They must rapidly accelerate heavy masses. They are used for frequent starting, stopping and reversing. They are subjected to severe abuse from inexperienced and careless operators and to exceedingly adverse conditions of temperature, moisture and dirt. For these reasons the entire mechanical structure of motors for railway, mill, mine or hoist service must be exceptionally rugged. The frame is of the closed or partially closed type, and the whole motor is extremely compact, in order that it may be installed in a confined location. The armature is of

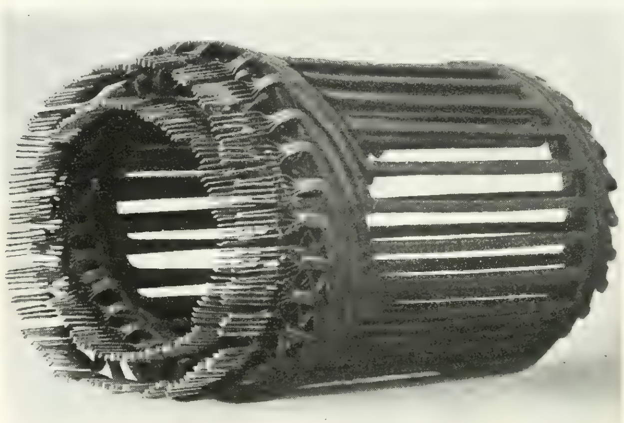


FIG. 71—STRAP COILS FOR A RAILWAY ARMATURE

relatively small diameter to permit of rapid acceleration and reversal, and is built to have maximum mechanical strength and to furnish as complete protection to the windings as possible. The coils are formed so that they nest snugly together, in order to support one another, as shown in Fig. 71. Extra insulation is supplied at every point of possible weakness, particular attention being paid to protection against vibration, and the consequent chafing of the insulation. In addition well insulated coil supports are provided, against which the coils are firmly bound by the banding wires.

PREPARATION OF THE CORE

The laminated core is assembled on a spider and compressed in a hydraulic press. Cast iron end plates, held by ring keys or ring nuts, serve to maintain this pressure, and at the same time serve as supports for the armature coils. As an additional support for the teeth, the last few laminations at each end are punched from heavier steel than the others. Ventilators are inserted at suitable intervals as shown in Fig. 72. The slots are accurately aligned during the assembly, but are further smoothed up with a file and the corners of the teeth are rounded off, to minimize the possibility of damage to the insulation. The

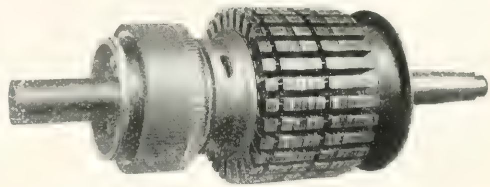


FIG. 72—CORE FOR WIRE COILS

shaft is then forced into the spider under a pressure of from 20 tons on the smaller motors to as high as 75 tons, which is sufficient to expand the metal of the spider slightly, and take up any possible looseness of core assembly. Heavy feather keys are used to prevent rotation of the spider on the shaft or of the core on the spider. Wiper rings are shrunk on the shaft next to the spider to keep oil from running into the armature. The core is then carefully balanced for static balance. Further balancing is usually unnecessary, as the windings are uniformly distributed around the shaft.

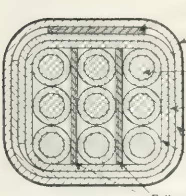


FIG. 73—CROSS SECTION OF WIRE COIL

Single coils arranged radially.

The commutator is usually pressed in place before the winding is commenced, except on a few of the mine or crane motors in which wire wound coils are used. It is mounted on the same spider with the core, so that the shaft may be removed from the completed armature without disturbing the windings.

THE COILS

Practically all modern railway type coils are completely formed before being assembled, so that they may be entirely insulated and impregnated with insulating compounds before being placed in position, and need no shaping after being placed in the core. As a rule, each complete coil is composed of two or more single coils

which are electrically distinct, but grouped together for mechanical reasons. These single coils may be formed from wire or from copper strap. The windings are of the wave or two circuit type, except on the largest sizes of mill or locomotive motors.

Wire Coils—The coils for smaller machines are made of double cotton covered wire. The single coils which form a complete coil are insulated from each other by fish the diamond end, as shown in Fig. 75, paper or fullerboard separators and may be arranged radially or circumferentially in the slot, as shown in Figs. 73 and 74. The leads from wire wound coils of modern construction are secured along and leave the coil one after the other, each being firmly tied and taped in position so that there is no possibility for them to chafe against one another. They are reinforced with cotton sleeves.

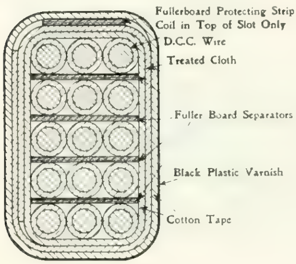


FIG. 74—CROSS SECTION OF WIRE COIL

Single coils arranged circumferentially.

Strap Coils—Most of the modern types of larger railway motors have the armature coils made from rectangular conductors instead of round wire, as with this form of conductor a greater proportion of the slot space may be filled with copper, without sacrificing the insulation requirements. The pressure on the insulating surfaces is also more evenly distributed, as with the round wire the pressure bears on a line, while with the rectangular conductors it is distributed over a flat surface and is much less liable to injure the insulation. Figs. 76 and 77 show a cross-section through two turn and one turn coils, respectively.

The one turn coil readily lends itself to bringing out the leads in positon to enter the top and bottom of the commutator necks respectively, by the use of the standard form of diamond end. The two turn coil, as shown by Fig. 78, requires a special turn at the rear end of the coil, in order to bring the leads out in the proper position. By the use of this form of coil, all the advantages of the strap winding can be secured for the smaller ma-

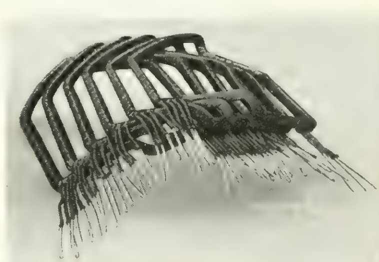


FIG. 75—WIRE COILS FOR A RAILWAY ARMATURE

chines, on which more than one turn per slot is usually required.

In some of the larger motors, coils of the rectangular types are made in two pieces, and are known as two piece coils. Their advantage lies in the fact that if a coil becomes damaged, only one-half of the complete coil need be removed to overcome the defect. As damage to the coils nearly always occurs on the outside of the armature, this type of coil is peculiarly adapted to railway type armatures. It requires, however, a soldered connection at the back, in addition to the usual soldered connection at the commutator, and hence is used only on the larger motors where the saving of copper for repair parts would be great.

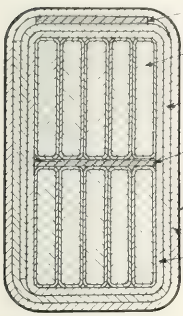


FIG. 76—CROSS SECTION OF TWO-TURN STRAP COIL

Coil Insulation—The insulation used on motors of the type under consideration depends largely on the type of coil used. Where double cotton covered coils are used there is little advantage in using materials for the remainder of the slot insulation which have higher heat resisting ability than the cotton strands which are in immediate contact with the conductors, since it is necessary under the circumstances to limit the temperature to values consistent with the cotton insulation. For this reason on certain types of mill motors, where the temperature conditions are exceptionally severe, asbestos covering is used instead of the cotton, with mica insulation around the complete coil, cotton being used only in the protective taping over the outside.

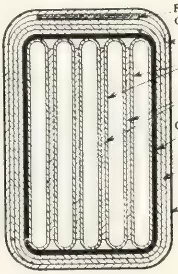


FIG. 77—CROSS SECTION OF ONE-TURN STRAP COIL

With strap wound coils it is possible to use built up mica in immediate contact with the conductors and cotton only on the outside protective coverings, where it is in contact with the air or the relatively cooler iron. Hence the copper can be safely worked to a higher value and continued overloads and abuse will not be so liable to cause breakdown. The coils are vacuum impregnated

before insertion in the armature. This process* renders them thoroughly moisture and oil proof and prolongs the life of the coils over that of the unimpregnated ones, especially where they are subject to moisture, acid fumes or deleterious gases. It is applied to all railway type coils, except those for mine locomotives, whose armatures are impregnated as a whole after the winding is completed. The impregnating process is, in general, one which can be duplicated in the field, except that it cannot ordinarily be carried out under vacuum. Good results can, however, be obtained by thoroughly drying the coils in an oven, then dipping them in the heated insulating compounds, and drying them afterwards in a warm, dry room.

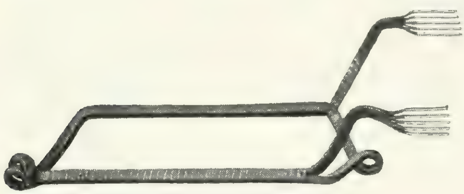


FIG. 78—TWO TURN STRAP COIL

WINDING THE ARMATURE

The winding of railway type motors differs from other types of winding only in the great care taken to secure extreme rigidity of mechanical construction. Extra protection is supplied at every point of special electrical or mechanical stress, i. e., where the coils leave the slots, where the leads leave the coils, where the leads cross one another or cross the ends of the coils, etc.

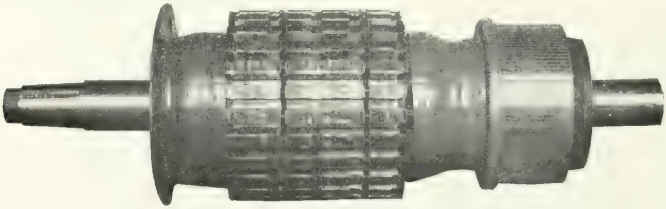


FIG. 79—CORE WITH COIL SUPPORTS INSULATED

Insulating the Core—As an initial operation, the core is cleaned thoroughly with an air blast. On machines for wire wound coils the coil supports have curved surfaces and are insulated with treated cloth in strips, or tape, as shown in Fig. 79. Slits are made in the strips where necessary to make them lie smooth, as over the end bell, care being taken that the slits in the successive layers are

*For complete description see the article on "Impregnation of Coils with Solid Compounds," by Mr. J. R. Sanborn, in the Journal for March, 1910, page 195.

staggered. These strips are bound together with shellac. They are built up to a thickness of about one-eighth inch over the entire support and to the level of the bottom of the slots and the commutator necks at each edge. Where this would require an excessive amount of insulating material, as occurs in the rear of the commutator on certain types, a bed of rope is built up, as shown in Fig. 80, and bound in place with an insulating cement. A final layer of friction tape is applied over all the insulation, great care being observed to make the layers lie smooth, and to build up a firm support for the coils where they leave the slots.

On the cores for strap wound coils, the coil supports are usually straight and are insulated with built up mica bushings or with heavy bands of treated cement paper. No tape is used in this case, but the bushings are arranged to come up level with the bottom of the slots.

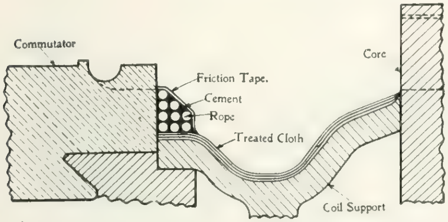


FIG. 80—INSULATION ON FRONT COIL SUPPORT

On both wire and strap wound armatures, the slots for about an inch at the ends are slightly wider than the coils, and narrow strips of heavy fish paper, projecting slightly from the slots, are inserted for additional protection to the coils at this point. The slots are further insulated with regular fish paper cells for the mechanical protection of the coils.

Inserting the Coils—Before starting to wind, the commutator is tested for breakdown with 5 000 volts to ground and 200 volts between segments. Two slots, separated by the proper throw, are marked with chalk for the first coil and the commutator bars into which the leads from these slots must fit are counted off from the bar opposite the center of the first slot. In a lap winding these bars should lie adjacent. In a wave winding, the number of bars between them is stated in the winding specifications. The first coil is then placed in these two slots, the bottom half being driven into the lower half of the slot, and the top half being merely caught in its proper slot, as it will have to be removed later, to allow a coil to be inserted beneath it.

Wire Coils—In the wire wound armatures the lower leads are taped with friction tape when necessary to make the insulation continuous from the coil to the commutator, and are laid along the

coil supports in smoothly fitting rows, and the bare ends driven into the proper commutator necks. Heavy insulation is supplied between the coil ends and the upper and lower leads and between the upper and lower coil ends. This may take various forms. In one type, shown in Fig. 81, treated canvas strips are inserted so as to furnish extra insulation between the ends of the adjacent coils and between the coil ends and the lower leads as illustrated. In addition a friction cloth strip, doubled over a piece of rope, is inserted at each end between the upper and lower coil as the coils are inserted, the rope fitting in the point of the diamond. The coils are shaped with a fiber drift and rawhide mallet so as to fit snugly against one another at both ends. It is very essential that they be made to fit closely together when first inserted as otherwise the armature will bulge at the ends, and any attempt to shape the coils in a completed armature is liable to injure the insulation.

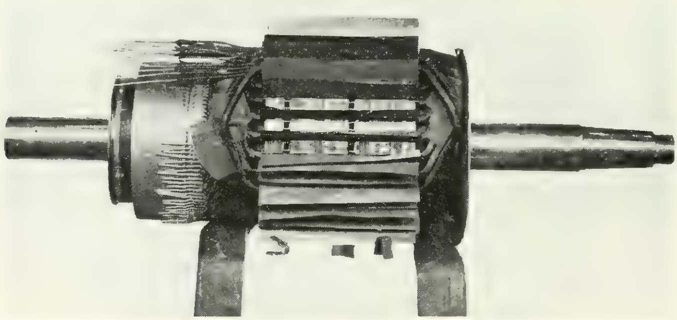


FIG. 81—CONNECTING THE LOWER LEADS

After all the coils have been inserted and the top parts of the throw coils have been replaced, the ends of the canvas strips which project up between the coil ends are trimmed off level with the top of the coils, at both ends of the armature. Those strips which project out from beneath the coils, are turned up over the coil ends, and are bound in place with friction tape. This tape is wound completely across the upper surface of the coil ends, and serves as a protecting and insulating layer between the coils and the upper leads.

In the type of armature shown in Fig. 82, two strips of treated canvas are slitted and inserted between the lower leads and the coil ends with the slits staggered. No strips are inserted at the rear end, and no insulation is supplied between the ends of adjacent coils, beyond that on the coils themselves. Strips of friction cloth and rope

are inserted between the upper and lower coil ends, and the canvas strips are folded over the ends of the coils and covered with friction tape as just described. In this case, however, strips of fish paper are slipped over each coil and wedged between the coil ends close to the core, as shown in Fig. 83, for further protection to the upper leads.

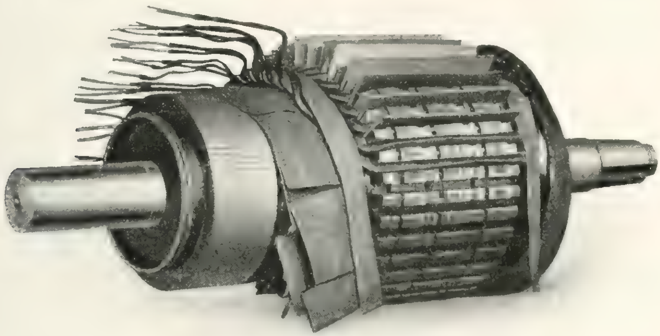


FIG. 82—INSULATING THE COIL ENDS

Before connecting the upper leads to the armature they are all tied together with bare copper wire and the coils are subjected to a break-down test of 3 600 volts. Any defective coils must be replaced. The armature is then trued up. This may be done by tapping down with a mallet all high coils, as located by holding a piece of chalk so that it will rub against the high parts when the

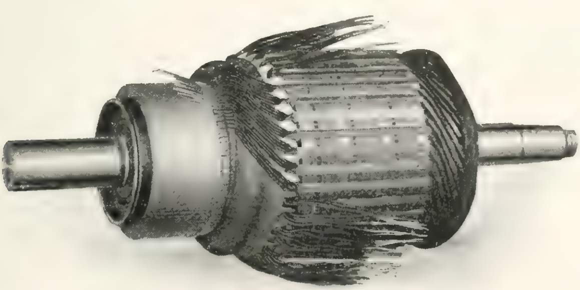


FIG. 83—CONNECTING THE UPPER LEADS

armature is revolved. A more approved method, however, is to squeeze the coils into place by means of a flexible metallic strap and turn-buckle. By this method there is less liability of damage to the insulation, and all of the coils receive uniform treatment, so that better balance of the armature is secured. Both ends must

form a compact and uniform mass. Where end room is especially valuable, as in mine motors, a special form is used on the rear end, against which all the coils are pressed when inserted, thus insuring absolute uniformity.

Where the top of the coil is above the top of the commutator, as shown in Fig. 84, there is sometimes difficulty in keeping the leads properly separated in bringing them down to the commutator. In such cases a canvas strip may be interwoven over every other one, making it possible to have two layers of leads on the vertical part. The leads are inserted into the slits in the proper commutator necks and copper wire dummies are driven over them, to prevent any possibility of a portion of the leads being removed when the necks are turned down. Both leads and dummies are tinned and are arranged to give a driving fit in the necks.

Strap Coils—The leads of strap wound armatures are formed

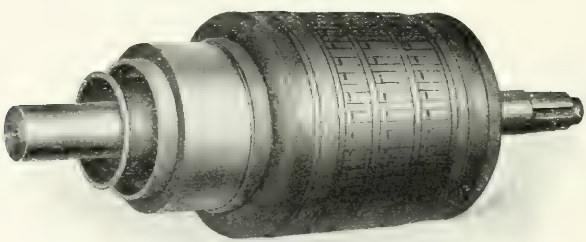


FIG. 84—COMPLETE ARMATURE, WIRE COILS

to shape and, therefore, require little bending during their installation. The coil supports of the two turn strap coils are shaped and insulated in a manner very similar to that for wire wound coils. In addition a bed of the insulating cement is made over the insulation at the rear of the commutator into which the lower leads are forced as they are inserted into the commutator necks. They are thus held rigidly in place after the paste hardens. Strips of treated canvas or of friction cloth folded over fish paper and mica are threaded between the upper and lower coil ends, at each side of the machine, as the coils are inserted. A length of rope is also threaded through the diamond point at each end. Between the coil ends and the upper and lower leads, strips of treated canvas with slit edges are inserted so that the openings will be staggered. The edge toward the core is shaped to fit up between the coils and furnish added protection to the leads. After all the coils have been inserted, the upper leads are bent up slightly, and the edges of the various in-

sulation strips are cut off even with the commutator. Friction tape is then wound smoothly over the treated canvas, holding it in place, and forming a bed for the upper leads. These are bent down, as shown in Fig. 85, and inserted into the proper commutator necks.

Coil supports for one turn strap coils, whether two piece or one piece, are straight, and are insulated with built up mica forms, or strips of fish paper or treated cement paper, shellaced and tied in place. Insulating cement is plastered over the insulation back of the commutator, which hold the leads from the individual coils in place. The ends of the coils are separated by two thicknesses of treated canvas, which are threaded in place as the coils are inserted.

The coil supports for two piece coils are insulated in the same manner as the one piece coils. The end bells for this type of armature, however, are separate from the core and are not put in place until the winding is complete, so that the winder has plenty of room to

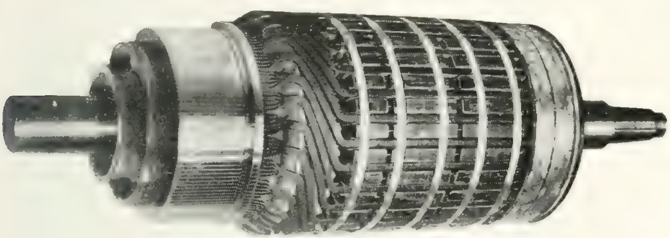


FIG. 85—STRAP WOUND ARMATURE, WITHOUT HOOD AT COMMUTATOR END

work on the rear end of the coils. The winding operation is greatly facilitated by the use of a steel winding jig of the form shown in Fig. 86. This jig consists of a slotted disk with a hub bored to fit the armature shaft. The number of slots is equal to the number of single coils in the armature, and the thickness of the disk equals the width of the connecting clips. As each coil is placed in the armature slot, the straps composing it are placed in the proper slots in the jig and in the commutator necks until all the lower half is in place. The leads on the upper and the lower half are separated by a couple of thicknesses of treated cement paper, or by a layer of fish paper and mica. A partly wound armature of this type is shown in Fig. 87.

After all the coils are in place, the straps which are to be connected together at the rear end lie one above the other in the slots of the jig. These are cut off even with the surface of the jig, a temporary band is wrapped around the coil ends, and the jig is removed. Copper connector sleeves are then slipped over the coil

ends and wooden wedges are driven tightly in between them. The connectors are then soldered and the coil ends are turned down at the top and side. The wedges are then knocked out, and asbestos braid is interwoven between the connectors to prevent accidental contact. The end bell is insulated with moulded mica or moulded paper, and is bolted into position.

Multiple Windings—Some of the larger sizes of mill and locomotive motors are wound with a multiple or lap winding. In such cases, cross-connecting rings are joined to equipotential points on the winding either at the rear of the commutator or at the rear end of the core. The only difference in winding is in the method of connecting the coils to the commutator. In the case of the multiple winding the end of each single coil goes into the neck adjacent to the other end of the same coil. Fig. 88 shows the armature of one of the Pennsylvania locomotive motors, which is wound with a multiple two-piece coil by the method just described. In this particular armature the cross-connections are at the rear of the core, and are connested to extensions cf the connecting clips, these special clips being used at regular intervals around the armature.

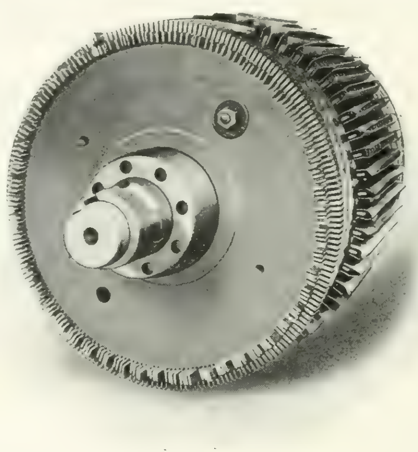


FIG. 86—JIG USED IN WINDING TWO PIECE COILS

SPECIAL CONNECTIONS

If in a four-pole motor with a two-circuit winding, there is an even number of single coils in a complete coil, one single coil in the armature must be cut out in order that the windings may be made continuous. This coil is called a dead coil, because it is not connected to the circuit. It is necessary first to determine the number of single coils in a complete coil, by dividing the number of complete coils, or slots, into the number of commutator bars. If there are more leads from each side of the coil than there are single coils, each single coil is composed of two or more wires in

parallel, and these must be treated as a single lead. In strap coils each strap corresponds to a single coil. The coil is cut out by cutting off the leads on both sides of one single coil, about an inch from where they separate from the coil and carefully taping them up. The body of the coil is left in the slot to secure uniformity.

TESTING

Before the coil leads are soldered to the commutator the winding is tested for correctness of connection with a special testing transformer. By means of this device either an open-circuit, a short-circuit or interchanged leads may be located at once.* If such a transformer is not available, an open-circuit may be located by ringing out between adjacent commutator bars with a magneto. If this test shows an open-circuit between any two bars, it probably means that the leads are interchanged either at this place or at the

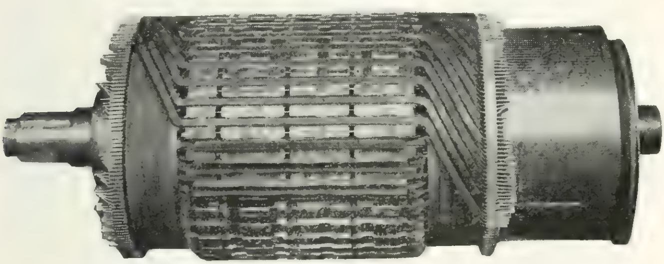


FIG. 87—ARMATURE PARTLY WOUND WITH TWO PIECE COILS

other end of the coil under test. Short and open-circuits may also be located by completing a buzzer and battery circuit through a portion of the armature, and listening through a telephone receiver whose terminals are connected from segment to segments. Failure to hear the buzzer at any point indicates a short-circuited coil. Failure to hear the buzzer at all points but one indicates that the circuit is open at this point. Neither of these latter methods is as reliable as one in which a comparatively heavy current flows when a defect is found, but may be used when the testing transformer is not available.

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*For complete description of this transformer see article II of this series, in the JOURNAL for July, 1910, page 551. See also method of testing railway armatures in the article on "Inspection of Car Equipment on Electric Railways," by Mr. M. B. Lambert, in the JOURNAL for April, 1910, page 318.

SOLDERING

After the windings have been tested the leads are soldered. Care must be exercised in doing this to prevent the solder from running down back of the commutator. Acid fluxes should not be used as the acid is very liable to damage the insulation, a solution of rosin in alcohol being recommended. A tin and lead solder doing this to prevent the solder from running down back of the commutator. Acid fluxes should not be used as the acid is very liable to damage the insulation, a solution of rosin in alcohol being recommended. A tin and lead solder

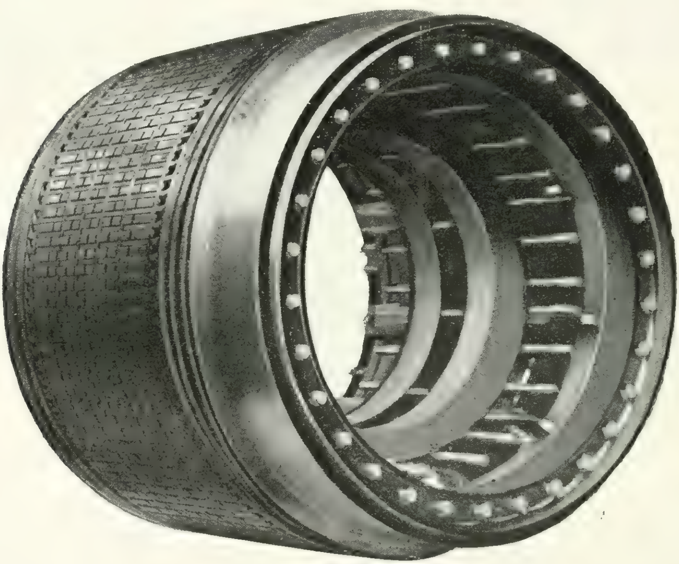

FIG. 88—ARMATURE FOR PENNSYLVANIA LOCOMOTIVES

is used in soldering leads to the commutator, but a pure tin solder is used in making all other joints on the coils, as the insulation is less liable to be damaged with this solder on account of its lower melting point. When tin is used the best results are obtained by working on the side of the armature, so that the joint is level. After soldering, the armature is mounted in a lathe, the rough solder on the commutator necks is turned down, the commutator is polished, and the wiper rings are turned to give the exact distance between bearings. Some few armatures have wedges inserted in the slots above the coils. These extend above the surface of the banding grooves, and are turned down while in the lathe, so that the banding grooves present a smooth bed for the band wires.

HOODING AND BANDING

As a final protection to the armature coils, heavy hoods are put on over the ends of the coils, covering the armature from the commutator to the core and from the core to the end bell. At the commutator end the hood is of woven asbestos sewed to a conical shape, and is impregnated in a moisture and oil repelling compound and put in place while wet. The small end is drawn up over the commutator, turned inside out, and firmly tied over the leads and commutator necks with heavy twine. The body of the hood is then turned back over the armature. If the commutator necks are lower than the level of the core, another layer of twine is wound over the hood near the commutator and a band of canvas sewed over the whole, as shown in Fig. 84. The hood is then stretched tightly back over the armature and tied with the twine.

FIG. 89—COMPLETE ARMATURE, ONE PIECE STRAP COILS

Around the rear end of the armature, a band of canvas is wrapped so that the greater part of the strip extends out over the shaft, only enough being wound over the armature to permit a secure fastening. This is bound in place with a band of twine wound tightly in the groove between the coil ends and the end bell. The canvas is then turned back over the armature and bound smoothly in place.

The number and size of bands depends upon the size and speed of the armature. All armatures have bands on each end, placed as far out as possible, and generally covering the greater part of the coil ends. When such a band would be quite wide, two separate narrower bands may be wound on each end. These bands are insulated from the coils by three turns of canvas tape

separated by treated cement paper, which extends at least one-eighth inch beyond the band on each side. The bands around the body of the core in the band grooves are insulated from the core and coils by strips of fish paper. They are put on with a tension of about 350 lbs., sufficient to make a good firm band and to bring the coils down so that they will not project above the surface of the coil at any point. The individual turns of the banding are well soldered together, and are further held at several places by thin copper clips, placed before the banding is started.

Completed railway armatures, showing the location of bands and hoods, are shown in Figs. 84 and 89. Figs. 90, 91 and 92 show the great similarity between railway and mill, mining and crane types of armatures. The methods of winding, and the insulation

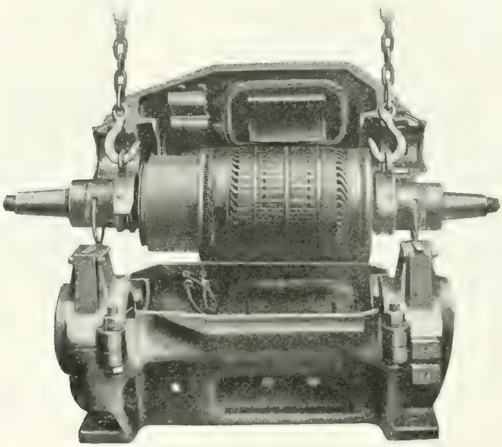

FIG. 90—MILL TYPE MOTOR

used throughout, while differing in some details, as noted, are practically similar, being modified in minor details only enough to make them more suitable for the special work for which they are intended.

After the banding is completed, the mica insulation between the commutator bars is undercut to a depth of about one-sixteenth inch, with a special milling cutter. The entire armature, except the commutator, is then sprayed with an air-drying finishing varnish.

ASSEMBLY TEST

Before the armature is finally approved, it is mounted in the frame and given a running test. To secure load conditions, two similar machines are coupled together, the one running as a motor

and the other as a generator. On the smaller sized machines the power delivered by the generator is absorbed in a resistance coil. On the larger sizes the loading back method is used, i. e., the two machines are connected in series, the generator furnishing part of the current required by the motor, only sufficient power to supply the losses in the two machines being furnished from an external source. Each machine in turn is run as a motor and its speed is measured at full load, and at twenty-five percent overload. If these speeds are within a few percent of normal the performance of the motor may be considered as corresponding approximately to that of the standard line to which it belongs. Readings of the resistance of the armature and fields are taken before and after this run, from which the rise in temperature of the windings can be calculated.

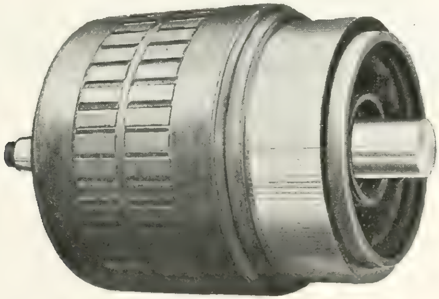

FIG. 91—MINE MOTOR ARMATURE

This temperature rise should not exceed 40 degrees C. for a one hour run at full load.

A close watch is kept during this test for all possible defects. Improperly adjusted brushes, a short or open circuit in the armature, incorrect field connections or poor magnetic circuit, etc., may be responsible for sparking. If the commutation is good in one direction and poor in the reverse, the brushes may be off the neutral position, or the neutral point of the armature may have been shifted by incorrectly connecting the leads to the commutator. Slight sparking at full load is allowable on non-interpole motors; but interpole motors should run sparklessly at all loads.

The motors are then disconnected and run above normal speed as a check on the banding and mechanical make-up of the armature and commutator. A careful inspection is made for any marked vibration, rubbing of the rotating parts on the frame or clicking

of the brushes which would indicate high or low commutator bars, or an eccentric commutator.

Defects in insulation are not liable to develop in the completed armature if the preliminary tests have been properly made. Careful tests are made on the assembled machine, however, after the windings have reached their normal operating temperature. For the first test, the fields are separately excited to full-load value, and the armature is run at full voltage without load. Maximum operating voltage is thus impressed between the armature turns and between commutator segments. Defective insulation may be readily located by local heating or smoking.

As a preliminary to the high voltage tests, a leakage test is

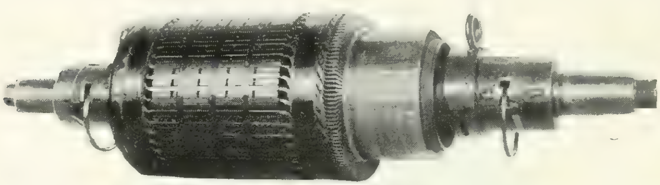

FIG. 92—CRANE MOTOR ARMATURE

made by means of a voltmeter connected in series with the insulation across a 500 volt circuit. The reading furnishes an indication of the condition of the insulation. If it is too high, the insulation probably contains moisture, or has been improperly assembled or impregnated. In this case a high-tension test is liable to cause a breakdown.

The final test is for breakdown to ground. High-tension alternating current is applied from the windings to the frame of the machine, for one minute. The voltage used depends on the size and characteristics of the motor, ranging from 2 600 to 3 600 volts. If no fault is discovered in the insulation, the armature is then ready for service.

POTENTIAL STRESSES AS AFFECTED BY OVERHEAD GROUNDED CONDUCTORS*

R. P. JACKSON

[This is the fifth of a series of articles dealing with the general subject of continuity of service in transmission systems, pertaining particularly to line stresses and static troubles and the proper protection of transmission systems.]

AN investigation of the potential gradients and the equipotential surfaces about grounded conductors suspended in the air, and also about metallic towers for supporting transmission lines, shows that such surfaces surround all conducting material subject to static strain, but the position of these surfaces and the gradient of change at different points are usually difficult to determine.

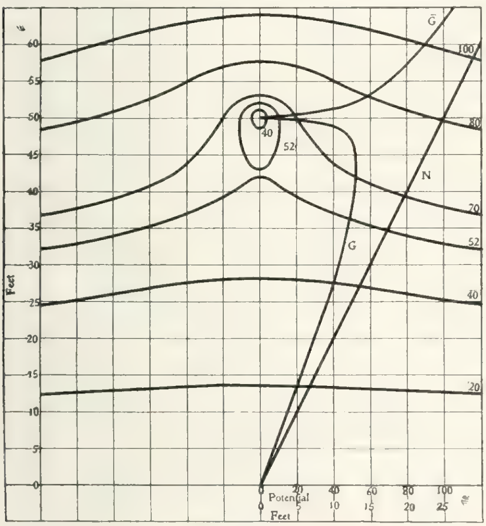

FIG. I

$$P = 2H - 27 \log \frac{R_1}{r_1}$$

The overhead grounded wire, placed above a transmission line as a protection against lightning, serves two purposes:—first, it interposes a grounded conductor between the sky and the transmission line and tends to relieve the line from direct strokes (the effectiveness of the grounded wire for this purpose will probably depend largely on its size and the distance between points at which it is grounded); second (a much more frequent condition), by acting as a static shield it serves to materially reduce the momentary potential occurring between the line wires and ground, induced as a result of lightning. It is reasonable to assume that there is a potential stress between a cloud and the ground, and that the distribution of this

*Revised by the author from a paper read at a special meeting of the American Institute of Electrical Engineers, under the auspices of the Transmission Committee, May, 1907, Chicago, Ill.

stress is nearly uniform, at least in the vicinity of the earth's surface; that is, that the potential due to the cloud is proportional to the height above the ground, and that the potential gradient is, therefore, approximately a straight line near the ground. Under these conditions it is possible to determine in what way this gradient will be altered by the presence of a grounded conductor some distance above the earth.

The potential at a point near an indefinitely long cylinder remote from other conductors is proportional to the logarithm of its distance from the center of the cylinder. If the potential at the point also tends to be proportional to its distance above the ground, its resultant potential will be the algebraic sum of the two. Obviously, the surface of the ground is iteslf an equipotential surface; for if it were not, current would flow from the points of high to those of low potential, and it would immediately become an equipotential surface. This fact, that the earth is conducting, cannot be represented mathematically, so it is necessary to assume an image of a charged object the same distance below the earth's surface as the real object is above, and that its charge is always of opposite sign. The surface of the earth then becomes of uniform potential without assuming that it is conducting. The equation for the potential P of a point near a grounded wire then becomes.

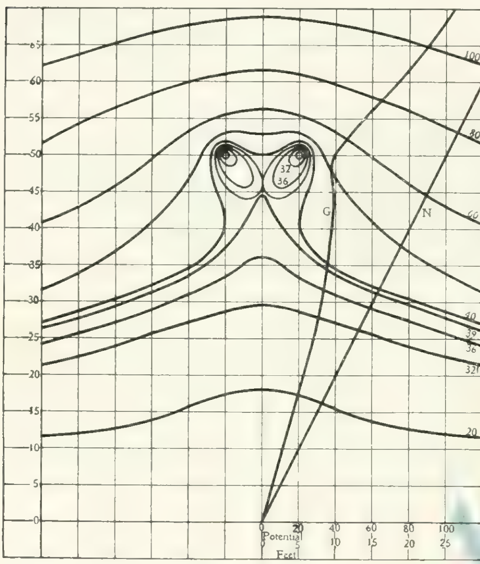

FIG. 2

$$P = 2H - 23 \log \frac{RR_1}{rr_1}$$

$$P = CH - K \log \frac{R}{r} \ldots\ldots\ldots\ldots (1)$$

where H is the distance of the point above the ground, C and K are constants, and R and r are the distances of the point from the image and the wire respectively. By taking the point on the surface of the grounded conductor, P becomes zero, r is the radius of this con-

ductor, while R is the distance to the center of the image of this grounded conductor, as indicated above. H, of course, is then the distance of the conductor above ground. The constant C is determined by the assumed gradient; hence, for one particular condition all quantities in the equation except K are known. Accordingly the question can readily be solved for the value of K, whereupon its proper numerical value can be used in the equation.

A wire 0.5 inch in diameter and 50 feet above the ground has been assumed for the case represented in Fig. 1. The gradient is taken at two units of potential per foot, so that if the wire were not there the potential at the point where it has been assumed would be 100. These figures given a convenient case for consideration, as the values deduced may also be used as percent ratios. The equation becomes approximately,—

$$P=2\,H-27\log\frac{R}{r} \;\ldots\ldots\ldots\ldots\ldots\;(2)$$

All of the curves of Fig. 1 are calculated from this equation.

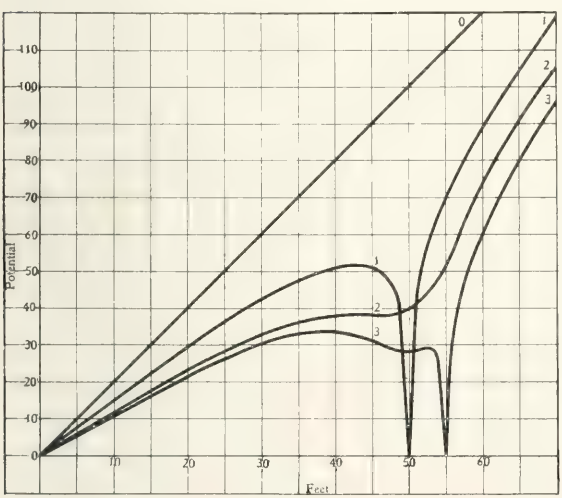

FIG. 3

It may be seen that at no point directly beneath the grounded conductor is the potential greater than 52. Curve G becomes the gradient instead of N. The meaning of this is that a transmission wire placed, say, five feet below the grounded wire would, when there was a charged cloud overhead, have a potential of about 55 percent of that which would exist if there were no grounded wire tending to cause a charge to leak from ground to the transmission line. Again, after the cloud has discharged there would be only 55 percent as great a potential on the wire and consequently only 55 percent as great a charge to escape suddenly to the ground. In other words, the curves do not indicate that complete protection is obtainable from a single wire, but that under certain conditions a

material reduction is dependent on the relative position of the transmission line and grounded conductor.

The equation given for a single conductor may easily be elaborated to cover any number of conductors of various sizes, distances apart, and heights above the ground. By taking the point for which the potential is determined by equation (2) on the different wires in succession, as many equations will be obtained as there are constants; accordingly the values of the respective constants may all be determined.

The equation for two grounded wires, ten feet apart, 50 feet high and 0.5 inch in diameter, becomes

$$P = 2\ H - 23\ \log \frac{RR_1}{rr_1}$$

Corresponding equipotential curves and potential gradients are shown in Fig. 2. It will, of course, be true that the protected area is considerably larger. In Fig. 3 is shown the assumed gradient, curve *O*, a straight line reaching a value of 100 at a height of 50 feet, and also the gradients on a medial plane for one grounded wire 0.5 inch in diameter and 50 feet above the earth (curve *1*); two 0.5 inch grounded wires, ten feet apart and 50 feet above the earth (curve *2*), and the same with an additional wire between them, placed five feet higher (curve *3*). If a number of wires were arranged either in a horizontal plane or cylindrically with the concave side towards the earth, a large area of low potential would be obtained, which would probably be a comparatively safe location for a transmission line.

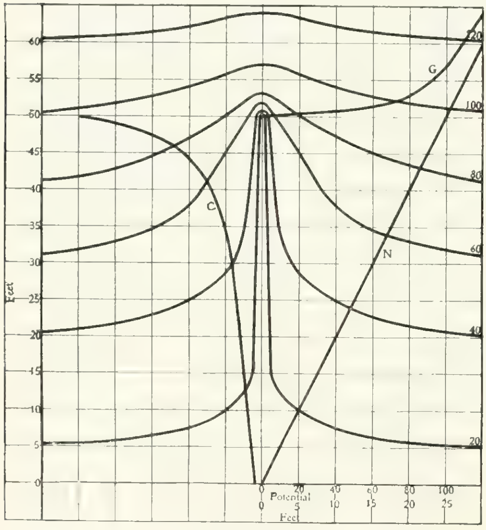

FIG. 4

Equipotential surfaces. One-inch cylinder, 50 feet high. N = Normal potential gradient. G = Potential gradient as modified. C = Comparative charge.

The above deductions are based on the assumption that the transmission wires are completely insulated, both from the ground

and from other parts of the circuit not affected by the cloud potential. Insulated uncharged conductors of small dimensions in the direction of the static stress have no appreciable effect on the static field about them. Such conditions, however, are practically impossible on a real transmission line, since it is reasonably certain that either the insulators will leak sufficiently to supply the small charge necessary to relieve the potential stress, or such charges will be supplied through a grounded neutral, if there be one, or by the capacity of the remainder of the circuit not affected by the cloud potential. In any case, the gradually developed stress due to the cloud will be relieved by charges appearing on the transmission wires, but when the cloud suddenly discharges by a lightning flash the charges on the line wires escape suddenly either lengthwise on the wires and into power stations, or over insulators at the point where the stress is greatest.

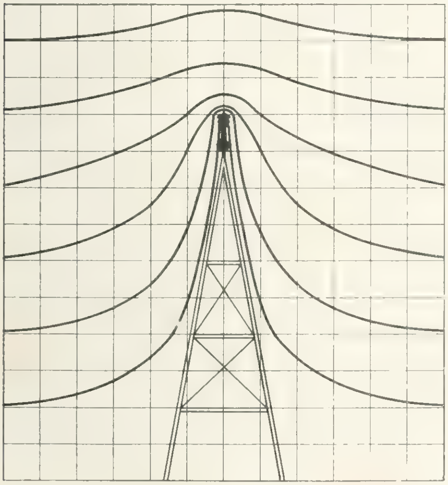

FIG. 5

By the fundamental principle of the conservation of energy, the potential stress which will cause a charge to appear on a wire will be reproduced in the opposite direction by that charge if the original stress be removed. This also holds good when a grounded wire is placed above a transmission line. Accordingly, although the curves of Figs. 1, 2, and 3 are calculated on the basis of perfectly insulated line wires, they hold equally good for an actual transmission line where the charges could readily find their way to the parts of the line under stress by the paths previously mentioned. This can be proven mathematically, independently of the principle of conservation of energy.

If the line wires were so insulated that only a partial charge could leak to them, the stresses at the time of lightning discharge would be reduced somewhat, but the grounded wire would still have the same beneficial effect. It is obvious that to get the full benefit of the grounded conductors, they should be frequently connected to the ground, as their effectiveness consists in releasing their own charge at the moment of a lightning flash, and immediately receiving

another of opposite sign from the ground. Otherwise the charges on these conductors, in suddenly returning to ground *after* a lightning discharge may induce excessive potentials in neighboring line wires.

It will be noted in Figs. 1 and 2, that the lines representing the equipotential surfaces are closely crowded together on the upper side of the grounded wire. The characteristic is much more marked in the case of a tower or spire projecting toward the sky. The potential of a point near such an object is much more difficult to calculate. Accordingly, in Fig. 4, a one-inch conducting vertical cylinder 50 feet high was assumed and the equipotential surfaces calculated. Curve *C* shows approximately the proportional charge at different points along the cylinder. Curve *G* shows the potential gradient from the top of the cylinder. This is a condition tending to produce leakage into the atmosphere, or corona effect, such as the St. Elmo's light seen at times on mastheads of vessels.

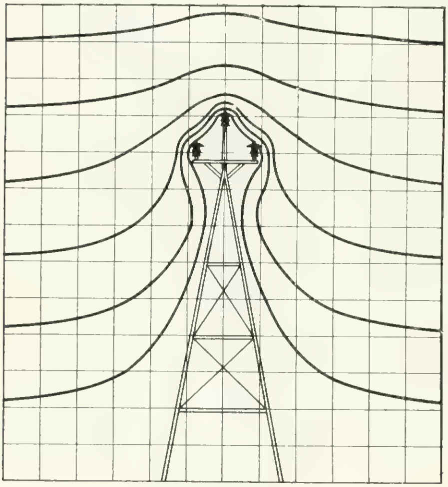

FIG. 6

Apparently, if an insulator were placed on the top of this cylinder and a high-potential conductor were carried by the insulator, a conducting state might be developed in the atmosphere about this insulator that would cause it to flash over, especially if there were any sudden rise of potential on the conductor carried by the insulator. Figs. 5 and 6 show two views of a metal tower under this condition. The natural suggestion for relief is shown in Fig. 7. If the tower structure were carried higher, and the transmission wires were suspended from insulators, the desired result would be obtained without the additional shielding device shown in Fig. 7.

All the discussion given in this article is, of course, purely theory, and if there were never any insulators broken, or other troubles arising from lightning strains, it would have no practical value. Insulators *are* broken, however; especially those carried on metallic towers. So, while the information given in the curves does

not indicate to any degree how much trouble can be eliminated by the devices discussed, they serve to give suggestions as to the most effective arrangement of such devices. If the line insulators are subjected to frequent stresses of a value five times that which they will stand, a reduction of 50 percent would not avail much. If, however, the average of normal stresses to which they are subject is only 150 percent of the breakdown value, a reduction of one-half in these stresses may eliminate a very large amount of trouble.

The general conclusions are as follows:

1—Properly placed and grounded conductors above a transmission line should materially reduce the electrostatic stresses to

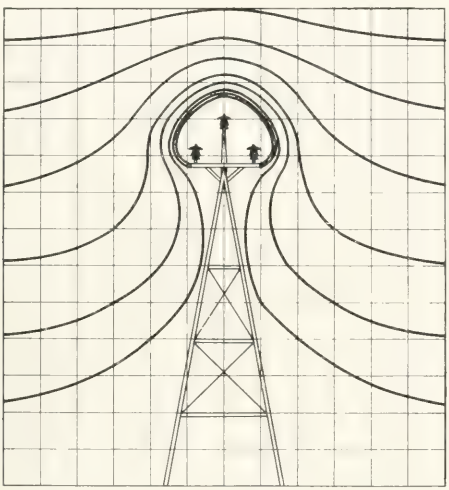

FIG. 7

which the insulators will be subjected.

2—An insulator interposed between a high metallic structure and the sky, without a grounded conductor above the insulator to act as a shield, is especially liable to breakdown.

3—An insulator of the suspended type interposed between a transmission wire and a grounded tower is better protected against electrostatic stress than an insulator mounted on a metallic pin projecting above the tower.

EXPERIENCE ON THE ROAD

A MYSTERIOUS SURGING OF AN ARC CIRCUIT

LEONARD WORK

A LONG-DISTANCE call for help from a small town where a street lighting system had suddenly failed, resulted in an engineer hurrying away on a seventy-mile trip to the scene of trouble. Arriving in the evening the town was found to be in darkness; a darkness which, combined with the prevailing fog, rain and mist, was almost tangible. The season was early spring, and a continual downpour had saturated everything outdoors, making an ideal condition for the development of grounds and line trouble. A dismal three-mile drive from the railroad depot over a muddy road which was also the course of the transmission line, brought us to the station, a water power plant, where the attendant, its sole occupant, was in despair.

The street-lighting equipment consisted of some twenty 6.6 ampere series arc lamps connected to the 2 300 volt system through a constant current regulator of the reactance type. The essential part of this regulator is a pivoted series solenoid through which current to the arc circuit passes. This solenoid, as it swings, surrounds a stationary iron core by a varying amount, thus increasing or decreasing the reactance. In operation, in case some lamps are cut out or otherwise short-circuited, the resulting slight increase of current pulls the solenoid further onto the core, whereupon the resultant increase of reactance in turn limits the current to practically its former value. To steady the action of the regulator and prevent hunting, a dashpot is provided which is filled with glycerine.

Upon closing the circuit so as to observe the action of the apparatus it was found that the regulator oscillated so violently and the ammeter indicated such a disturbance that the switch had to be immediately opened. A careful inspection of the regulator showed it to be in perfect order except that the solenoid could be moved with the utmost freedom. No opposition was offered by the dash-pot, as the glycerine had been intermediately thinned down by the addition of alcohol. This useless mixture was throw away and replaced temporarily with dynamo oil. After some adjustment of the by-passes in the plunger, the dash-pot was again in a condition to resist any sudden movement of the solenoid. Upon reconnecting the arc circuit the regulator came quickly to a point of balance and

the ammeter indicated that the lamps were receiving a steady and normal current.

The councilmanic committee which was present—for this was a municipal plant—followed with great interest every move of the visiting engineer and saw him remove the apparently simple difficulty with seeming directness and ease. They were accordingly pleased and seemed disposed to laugh in derision at the discomfited attendant.

The engineer, however, with caution born of experience, refrained from joining in the general gayety and quietly waited, with a vague intuitive feeling that still other trouble would develop. Strangely enough, after the arc circuit had been on for about a quarter of an hour, and the likelihood of any further trouble seemed very remote the regulator gave a violent "chug," and at the same instant the arc circuit ammeter showed a momentary increase of current to about twenty-five percent above normal. In a minute this recurred and finally began repeating itself some four or five times a minute. It was as if a loop or portion of the arc circuit was being cut out by a swinging ground or short-circuit or as if a narrow gap at some point where a potential existed was being intermittently bridged, thus causing momentary flashes.

Obviously there was trouble on the line, a view which was strengthened by consideration of the weather conditions; accordingly, a midnight tour of the line was proposed. As this was a novelty to the lighting committee they went along. Locating the trouble would, of course, seem to be an easy matter. If a loop of lamps was being intermittently cut out by a swinging ground they would be extinguished while the other lamps would brighten up; moreover, the inevitable flash at the grounding or short-circuiting point would be easily seen in the dark; nothing could be simpler.

Nevertheless, throughout the inspection trip none of the expected indications was observed; all the lamps flashed alike, and, moreover, the series tungsten lamps, now and then encountered, each showed a brightening which beyond doubt was evidence that the surge of current affected all parts of the circuit alike. Reflecting on this fact, it was apparent that such a condition could hardly be caused by a ground or short-circuit, and so far the cause remained a mystery. It was now long after midnight and the fruitless search was finally abandoned, as all of the party were fatigued and chilled from exposure.

On the following day it was decided to examine a couple of

the arc lamps which the night before appeared to be somewhat more disturbed by the surging than any of the others. On inspection, one of these was found to have lost a portion of its dashpot, and the comment of the electrician was that this one was his "most freely working lamp." It was found to be very unstable, slight variations in current causing its operating mechanism to make violent and spasmodic fluctuations before becoming quiet. Another lamp had a broken starting resistance, the free end of which was in loose contact with the moving mechanism. The behavior of this lamp was identical with that of the former one.

Three lamps were also found whose cut-out springs were so bent that contact would be made before feeding the carbons. It seemed probable that the surging occurred about as follows: The lamp with the broken starting resistance would short-circuit itself whenever the broken wire touched the lamp mechanism, the resultant increase in current would cause the lamp with the defective dashpot to pull up far enough to close the cut-out contacts, and thus further increase in current would cause a couple of the lamps with defective cut-out springs to close contacts. The cutting out of four or five lamps occurring almost instantaneously caused an increase of current in all the lamps in the series and thus disturbed the entire circuit, including the regulator. The lamps were at once put in good condition and restored to service, since which time no further surging has occurred.

This small but well equipped plant is attended by only one man who acts as operator, lineman and electrician combined. It had been in operation two years without a serious case of trouble, save a single instance, when one day an amateur wireman left a transformer short-circuited so that, when power came on, the transformer was burned out.

The electrician in describing the peculiar action of the generator on starting up at the time of this short-circuit, stated that he "knew somehing was the matter as the machine wouldn't give any volts; all it would give was amperes."

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

486—**Early Generator Efficiencies**—In an interview with Thos. A. Edison, published in Munsey's, he is quoted as saying of the early dynamos, "Only half of the energy put into them could be taken out, and by Ohm's Law, it was declared to be impossible to improve them." Also (after he had made a machine of more than 50 percent efficiency) "Your law is gone—it is not a law, but an error." Please state what reasoning from Ohm's Law gave the idea that more than 50 percent efficiency was impossible.

E. E. G. R.

Ohm's Law was wrongly interpreted in the early days. Siemens, Gramme and others built dynamos in which the external resistance and the internal resistance of the dynamo were sought to be the same, just as the maximum output of a battery was the greatest when the internal and external resistance was the same. This absurd practice was defended by one well known electrician as late as 1880, in the *Scientific American*, and he states that my statement that I got 90 percent of the energy in the external circuit was absurd and contrary to Ohm's Law.

T. A. E.

487—**Parallel Operation of Alternators**—In a power plant in which there are two 75 kw, 2300 volt, three-phase, 300 r.p.m. direct-connected generators it is observed that, with one machine running, the current per phase is 13 amperes, while with identically the same load and the second machine operating in parallel with the first, the load is 13 amperes per phase on each machine. Is it probable that the latter condition is caused by angular variations in the speed of the fly-wheel throughout the revolution, causing cross-currents to be set up in the alternators? If so, how may the trouble be corrected? These machines have been operating in this way only recently, and without any change in the switchboard connections having been made. Please advise of all possible causes for such action.

H. W. R.

This action may be due to hunting, as suggested. If so, there will be a periodic fluctuation in current. The trouble may also be due to wrong field current adjustment, causing an out-of-phase current to circulate between the two machines. This can be checked by simply measuring the field currents of the two alternators, which should be equal. As explained in an article by Mr. Geo. I. Rhodes in the JOURNAL for July, 1907, pp. 382-3, circulating currents will always occur if there is any phase displacement, change of magnitude or of frequency of one or more of the generated e.m.f. waves of two or more alternators operating in parallel. These circulating currents are caused by an unbalanced potential. The phase displacement and variations in magnitude of the generated e.m.f. waves may be produced by several causes, such as a change in excitation, a momentary fluctuation of angular velocity or a permanent change in the driving torque of one or more of the machines operating in parallel. It has also been found in some cases, where the tendency to hunt arises from irregularity in the driving torque of the engines that the trouble could be lessened or even entirely corrected by synchronizing the strokes of the two engines. See

"Notes on the Construction, Performance, and Operation of Alternating-Current Generators," by Mr. P. M. Lincoln, in the JOURNAL for Oct., Nov., and Dec., 1906, pp. 549, 631, and 680. F. D. N.

488—Operation of Tirrill Voltage Regulator—Can you suggest any reason why the time of vibration of the contacts of a Tirrill regulator increases as the load on the generator increases? Is the time of vibration affected by the power-factor of the load or by changes in the speed of the generator due to poor regulation of the driving engine? At what speed do the contacts of a regulator ordinarily vibrate? The regulator to which I refer is connected to a 200 kw, 2200 volt, two-phase, 60 cycle, 600 r.p.m. generator which is excited by a 75 kw, 1200 r.p.m. compound-wound machine, compounded to increase the field voltage of the alternator from 118 volts at no load to 125 volts at full load on the exciter. May the fact that the regulator holds the exciter voltage at about 100 volts for about three-fourths of the time, be a possible cause of sparking at the brushes of the exciter? T. G. W.

As explained in article on "Regulators for Alternating-Current Work," in the JOURNAL for Sept., 1908, p. 502, the Tirrill regulator accomplishes regulation by cutting in and out the exciter rheostat resistance. This resistance is cut in for a greater length of time at low voltage and is cut out for a greater length of time at high voltage. Therefore the speed of the relay contacts must necessarily be greater at a low than at a high exciter voltage. Any change in the power-factor of the main generators which causes the exciter voltage to vary will also change the rate of speed of the relay contacts. The effect of an increase in the speed of the prime movers is that less excitation is required and the speed of the relay contacts is therefore varied accordingly. One condition that can alter the speed of the relay contacts in the reverse manner is that which occurs when the regulator is operated in connection with an over-compounded exciter which is supplying the field current of an over-compounded or self-regulating alternating-current generator. In this case it will be apparent that both generator and exciter require actually less voltage on the exciter shunt field as the load increases. Tirrill regulators have no effect whatever on the sparking of the brushes at the commutator. A. A. T.

489—Ultimate Strength of Cast Iron—A piece of cast iron shaped to a section one-half inch square was tested for breaking strength by clamping it in a horizontal position, in a vise, and applying weights supported by piano wire at a point five inches from the point of support. The piece did not fail until a weight of 210 lbs. was applied, although it was figured that it should break with about 85 lbs. weight. Please explain this apparent discrepancy. H. A. F.

The ultimate strength of cast iron is not a very certain quantity, as its physical properties vary so greatly with varying chemical properties; it may vary from 10 000 lbs. to 35 000 lbs. per sq. in. or more, depending upon its quality. Hence, both of the above figures are within reason. A test such as that described is greatly affected in the results obtained by the manner in which the test piece is supported, i. e., whether it is clamped under small or great pressure, and whether the edges of the jaws holding the piece have sharp or round edges. R. S.

490—Size of Exciter Required—What is the most accurate method that may be used to determine the size of exciter required for any given size of alternator, either single or polyphase, especially three-phase? G. M. B.

No definite rule can be specified which will be generally applicable. The size of exciter required for a given alternator depends entirely upon the inherent characteristics of the alternator, such as the power-factor on the basis of which

its capacity is figured, the degree of induction at which the iron is operated to give normal voltage, etc. Note paragraphs on "Excitation," in the article on "Alternating-Current Generators," in the JOURNAL for Dec., 1906, p. 681.

J. B-W.

491 — **Phasing Out Addition to Transmission Line** — We will soon have occasion to connect several miles of additional line in parallel with a line already in service. Please give diagram of connections which will serve to phase out the new line with the old one, as we do not want to make any changes in connections at the load end of the line. The line voltage is 2 300 volts. The transformer connections are three-phase, delta to delta. The load in question is 800 hp. The transformer method of phasing is preferred. G. M. B.

The respective sides of the new line may be connected to those of the old at the generator end without regard to phasing. The selection of phases for paralleling at the load end may be carried out as indicated in Nos 157 and 256, just as though two synchronous machines were to be paralleled.

492—**Testing Conductivity of Ground Plates**—How may the effectiveness of earth plates buried, say, six feet in the ground, be determined? Would it be effective to bury an extra plate about 100 yards distant from the one to be tested and measure the voltage drop between the plates when a current of 20 to 100 amperes is sent between them? Assuming that an alternating-current testing circuit of 50 cycles and ordinary switchboard instruments are available, could a satisfactory test be made, or would it be affected by charging currents? What would be the effect of such charging currents with the plates 100, 400, 800 and 1600 yards apart. L. G. R.

For testing ground plates the best known method is to measure the resistance by alternating-curcurrent at 220 volts, applied between the plates and some very good ground such as a water-wheel penstock of iron or a water or gas main. The next best method would be to make an additional artificial ground, as suggested, and measure the total resistance between them, assuming that the respective drops are equal. If three such grounds are used the approximate resistance of each may be determined as illustrated in the following example, designating the respective plates as A, B and C, and assuming the measured resistance from A to B to be ten ohms, as given by the current and voltage drop; that from B to C, nine ohms; that from C to A, eight ohms; then, the respective values of A, B and C may be solved algebraically:

$$A + B = 10 \ldots\ldots\ldots (1)$$
$$B + C = 9 \ldots\ldots\ldots (2)$$
$$C + A = 8 \ldots\ldots\ldots (3)$$

Subtracting (2) from (1) and adding this to (3): $2A = 9$; $A = 4.5$. Then substituting this value in (1): $B = 5.5$; likewise $C = 3.5$.

If the voltage employed for the test is sufficient to overcome errors due to polarization of the plates, the results would probably not be materially affected by charging current errors at ordinary commercial frequencies. Ordinarily the distance apart of the plates will not make a very great difference in the resistance between them as the areas become very large a few rods distant from them and the current density correspondingly small.

R. P. J.

493—**Theory and Operation of Asynchronous or Induction Type Generator**—Please give some information relative to the theory and operation of wound rotor induction motors used as synchronous generators. J. C. B.

An induction motor operated above synchronism and connected in parallel on a circuit will not affect the voltage, i. e., the asynchronous generator will deliver current into the line at the same voltage and frequency as that of the line. The amount of current which will be delivered depends on the speed and on the amount of resistance in the secondary circuit of the induc-

tion generator. With a constant resistance in the secondary circuit the amount of current delivered to the line will be affected either by changes in the frequency of the line circuit or by change of speed of the induction generator. For further data on operation of asynchronous generators connected in shunt across the line, see paper by Mr. W. L. Waters, Trans. A. I. E. E., 1908, Vol. XXVII, pp. 157-180, and discussion of paper by Mr. W. S. Lee on "Parallel Operation of Hydro-Electric Plants," (Apr., 1910), Proc. A. I. E. E., Aug., 1910, p. 1401. See also Nos. 107 and 428, and p. 498 of the JOURNAL for June, 1910. If an induction motor is connected in series on a circuit and is driven above synchronism, the line voltage will be increased, i. e., it will act as a booster. The amount of the generated voltage depends on the general characteristics of the induction motor or generator, such, for example, as the effective resistance and reactance and the speed of the machine; it also depends upon the current in the line circuit. Yet it should be mentioned that the main disadvantage of an induction generator lies in the fact that the power-factor is always below 100 percent unless the lagging wattless component which causes the reduction in power-factor is compensated by means of a separate over-excited synchronous machine or other source of leading wattless component. Finally if an induction motor is run in a direction opposite to that of its normal rotation as a motor, the machine will still have the characteristic of an induction motor, i. e., it will not deliver any energy into the line but will draw sufficient energy from the circuit to cover all the losses in the motor. If full voltage is applied to the motor the amount of current will be equal to or somewhat above the "locked" current, i. e., the current will be very high, unless a high resistance is inserted in the secondary circuit. The frequency of the current in the secondary will be double the frefrequency in the primary circuit if rotated at synchronous speed, as the secondary frequency is equal to slip × primary frequency. See formula for determining secondary frequency given in article on "Speed Control by Frequency Changers" in the JOURNAL for Oct., 1909, p. 612.

H. C. S.

494 — Transformer Design — Size and Length of Wire—In transformers of different capacity, but of the same voltage, is the length of the wire in the windings the same? What is the size of wire in the primary and secondary of a 100 watt and a 100 kilowatt transformer? What is the length of this wire in these respective transformers if wound for 13 200 to 110 volts? Is there any simple method of finding the length and size of the windings for a given capacity and voltage?

H. R. K.

For the same voltage, as the capacity increases the number of turns decrease but the length of each turn increases. The total length decreases, but not nearly as rapidly as the capacity increases. If the space-factor, etc., were constant the total length of conductor would vary inversely as the fourth root of the capacity. For transformers of the same type the current density is approximately the same for all sizes, so that if the voltage remains the same, the cross-section of conductor is proportional to the capacity. There is no simple method of finding the length of conductor for a given capacity and voltage, but the cross-section may be determined after the number of amperes per square inch is decided upon. For a 13 200 volt to 110 volt, 60 cycle transformer the following figures would be reasonable:

	Cross-Section	Length
100 watts—		
Primary	0.000065 sq. in.	24000 ft.
Secondary	0.0078 sq. in.	200 ft.
100 kw—		
Primary	0.0065 sq. in.	6000 ft.
Secondary	0.7800 sq. in.	50 ft.

The primary of the 100 watt transformer is so small that in practice it would be necessary to use a larger wire for mechanical reasons.

E. C. S.

THE

ELECTRIC JOURNAL

Vol. VII NOVEMBER, 1910 No. 11

Squirrel Cage Motor Applications

The increasing popularity of the induction motor and its application under widely varying requirements, makes welcome an addition to the literature dealing with the selection of the proper type of machine for a given service. Mr. Hellmund's article on "Squirrel Cage Induction Motors with High Resistance Secondaries," in the present issue, has a double value in first analyzing, in each case, the problem which justifies the use of a motor having the characteristic under discussion, and second in determining quantitatively just how far this effect may be carried to commercial as well as technical advantage.

Increasing the resistance in the squirrel cage armature of a normal induction motor is usually productive of three immediate results: First, increase in slip, which means a decrease in the full-load speed; second, increase in starting torque, and third, decrease in full-load efficiency. The first of these conditions lends itself exactly to work in connection with a fly-wheel, the second makes available a larger starting effort to overcome friction or the accelerating inertia and the third, while apparently a direct disadvantage, is so overbalanced by the results from the first and second that the all-day efficiency is actually increased where the load is fluctuating. Mr. Hellmund has nicely balanced the advantages secured by these inherent characteristics and shown how the best results are to be obtained by giving each its proper weight.

There are two well-known facts brought out in connection with fly-wheel work which are worth noting; the first and fundamental one is, that a fly-wheel cannot store energy and restore it to a system without an actual change in speed. A common conception of the fly-wheel is that, by virtue of its inertia, it prevents increases and decreases in speed and thus acts as a mechanical dash-pot or regulator. In many cases this is apt to be an error or at best a half truth, since the fly-wheel is introduced into the system to

transfer energy from one part of the cycle to another and can only perform this function by actually changing its rotative speed. This brings out the second fact, viz.: if the fly-wheel is to change in speed it must not be driven by a motor with close speed regulation or, in other words, running at too constant a speed over a wide range of change in torque or driving effort. To use a homely phrase, for proper operation the motor must "lie down" when the heavy loads come on, so as to allow the fly-wheel to deliver a portion of its energy of rotation, and when the peak load is past it must again accelerate the fly-wheel mass in order that it shall recover this lost energy. The advantages of this action and the limits to which it may be carried are carefully worked out in the present article.

It is worthy of note that, in his discussion of the advantage to be secured by the right use of a fly-wheel, Mr. Hellmund covers all of the elements which make up the cost of a motor during its entire life, viz.: first cost, which may be decreased by a possible reduction in size of motor; the cost of power or of operation, both of which may be directly reduced by improving the all-day efficiency and equalizing the line load, and depreciation, which is decreased by reducing the mechanical stresses.

It is certain that the judicious employment of a type of squirrel cage motor of the characteristics indicated would bring about a most gratifying improvement in the operating conditions of many industrial plants. A. M. Dudley

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Calculation of Rotary Converter Performance

In the article on "Voltage Regulation of Compound Wound Rotary Converters," in this issue of the Journal, Mr. Bache-Wiig deals ably and lucidly with a rather difficult and intricate subject. It is possible, at best, to obtain an approximation of the combined effects of reactance, resistance, and armature reaction in rotary converters, but Mr. Bache-Wiig has shown, first, that such approximation is all that is needful, and, secondly, that a simple solution is feasible and in conformity with practical results. Inquiries received through The Journal Question Box indicate that Mr. Bache-Wiig's article will be of timely interest to many Journal readers and we commend it to those who have thought about the subject, and desire a simple treatment of an important practical problem.

B. A. Behrend

Specialized Apparatus

The terms "special" and "standard" as applied to electrical apparatus must always remain relative rather than precise. Special apparatus is to be avoided whenever possible, and to be used only when no existing standard machinery can be made to fulfill the requirements. A penchant for special apparatus presupposes a long patience and a longer pocketbook. But apparatus that is special today may be standard tomorrow. It is a matter of reduplication within a reasonable time. Special apparatus that will be called for again and again at frequent intervals takes a place intermediate between standard and special and may be called "standard-special," "special-standard" or "specialized" apparatus, as the fancy dictates.

The last five years have seen a drift toward lines of machinery of this sort, and especially is this true in the case of motors. The indications are that increasing amounts of business will be done in the special-standard lines as time goes on. The very tendency of electric drive to spread to new fields is conducive to this development. The recent expansion of motor drive into the textile field provides an excellent example of the way the modern designer meets special requirements with special machinery.

Cotton mill service imposes peculiar conditions. Three items are of predominating importance:—

Power is a large item; accordingly the motors must have more than ordinarily good electrical characteristics.

The working conditions are bad, due to hot rooms, continuous service and a lint-laden atmosphere; the motors must, therefore, be cool-running and dust-proof throughout.

Uniformity of speed is a paramount feature; maximum production of uniform quality being the one great desideratum.

Induction motors are used throughout in textile work. Standard motors are partially successful in this service, but to reap the rich harvest that was seen to be ripening it was early realized that a partial success would be a failure, whereas a motor designed to meet the conditions would assure success. Accordingly, exhaustive studies of motor operation in cotton mill service have been made in many mills and extending over a number of years. A distinct type of motor has resulted, as described in the article on "The Textile Type Motor," in this issue of the JOURNAL.

The points of interest here are not the refinements in design by which the result was accomplished, but that it *was* accom-

plished and that its accomplishment has opened up a field for motors, which would never have grown to any extent with the continued use of standard apparatus. Not only has the demand justified the making of a motor, but this has been accompanied by the development of special control apparatus as well.

The significant feature of the matter is that however successful and desirable standard forms of apparatus may be, it is often undesirable to force their application to a class of service in which they could not operate with full success.

In many cases the number of motors used does not justify the design of special forms, but in other cases, such as for heavy mill work, and for textile mills, the use of motors has grown so great that the peculiarity of each situation can be squarely and fully met with apparatus specifically suited for the service.

Securing Off-the-Peak Load

A good day-load is the ideal of every central station manager. How to secure such a load, is his chief problem. Very few industrial plants are being changed over from mechanical to electric drive through sentiment alone. It is necessary to show that economies will result. What these economies are, the central station solicitor must determine by a careful study of the particular industry and the plant itself. Conditions in the same industry vary in different plants and economies possible in one place are impossible in another. Hence, any specific statement must be based upon a detailed study of the operating conditions.

The first essential in entering a load-factor increasing campaign is good service. Contracts with prospective power users should be discouraged until the central station can furnish reliable service, for no difference how urgent may have been the demand for power, yet after service has begun no excuses are acceptable for interruptions.

A second consideration is the personnel of the organization from the coal-heaver up. There should be a spirit of co-operation and belief in the excellence of the company, and a common endeavor to make the service reliable and efficient. All should see that complete success of the individual is only realized in the success of the company as a whole, and that this is measured by the satisfaction of the customers. Solicitors in particular should be chosen from those who understand and believe in the value of central station power. They should be men who have an honest

conviction that purchased power is the best, and they should have ready the reasons for this belief. The great majority of power contracts from 10 to 100 horse-power are closed because the customer believes in the solicitors' recommendations.

A third essential is the general policy of the central station company. Its representatives should understand that it is efficient service rather than mere power that is furnished to its customers. The customers must be brought to see that the central station is interested in securing the most economical operation of his plant even though it may not increase the revenue derived from his installation. Such an impression among the users of central station power will make them ready to assist in securing other installations. This will place the central station in the position of a consulting engineer and friend, so that its recommendations will be accepted not only as to the installation of additional equipment, but also as to the most suitable type of apparatus. This will enable the central station to control in a large measure the power-factor situation and the grade of apparatus installed, which are important items where power and lighting loads are operated from the same mains.

A fourth essential is a good record of installations which have already been made, with information regarding the machines and the power consumed. A central station without such a record may be likened to a library without an index. While there is plenty of information at hand, it is too difficult to locate when needed. A printed reference card is a satisfactory form for recording such information, and rendering it available. These cards should give the name and location of the consumer, the class of work, the meter and transformer capacity, the voltage and other characteristics of the circuit, with a short description of the motor and machine equipment. Also the number of men employed, the approximate output, the hours of operation per week, a monthly statement of the power consumed in kilowatts, and the average load-factor. When there are a large number of cards, they may be conveniently filed according to the industries represented, thus permitting ready reference.

A fifth essential is an advisory engineering service to be rendered by the central station. Stations which can afford a consulting engineer with a good all-around mechanical and electrical training and a goodly amount of common-sense, have a distinct advantage. Such a man should be at the call of the customers, and

can render much valuable assistance to the operating department, as he will continually be building up confidence in the company, and will contribute to economical and successful operation by seeing that proper sizes and types of electrical equipment are installed, and are properly operated. He will be of special service in connection with new work, advising as to the best methods for electrical operation, and also as to the economies which may be secured. In cases where such an engineer cannot be secured, advantage may be taken of the engineering experience in the installation and use of motors which is afforded by the motor manufacturers; in fact even when an engineer is employed, his work may be supplemented and broadened by the wide experience of the representatives of the motor manufacturers through the valuable central station data on power installations which they are continually gathering for use in this kind of work. In machine shops and woodworking plants, for example, the great tendency is simply to apply motors to a few line shafts and make but few changes in the drives of the machines. While this is undoubtedly an improvement in the operating conditions of the shops, it will not secure for the customer the greatest advantages of electrical power. The solicitor should in all cases endeavor to secure the maximum return to the customer per kilowatt-hour of energy sold. This is not only good engineering, but it is good business policy, as the best stepping-stone to future customers is the successful and economical operation of present service.

The business of building up an off-peak load requires a large grasp of the situation, and an intelligent use of all the means at hand. Experience demonstrates that it can be done. The great development in the use of motors on central station circuits is one of the most notable features in recent central station development; but it comes only to the progressive central station. Coupled with a broad policy, a good working plant and a pull-altogether spirit, there must be individual optimism. After all, it is the human element that really counts and mere organization is helpless unless the spirit of optimism reaches from president and manager to solicitor and trouble clerk.

Harry G. Glass

ELECTRICALLY OPERATED SHOVELS

W. H. PATTERSON

DURING the past six years great strides have been made in the application of electricity to power operated shovels. At present a number of them are being successfully used in grading operations, gravel pits, stone quarries, brick and tile yards, cement plants and in placer ore mines. These shovels are fully equal in power and capacity to steam shovels and may be built for any service desired.

EQUIPMENT

The mechanical equipment of an electrically operated shovel, i. e., the dipper, boom, car and trucks, is built along the familiar lines of the steam shovel. The power equipment consists of a motor of from 50 to 200 horse-power to operate the hoist, and two motors of from 25 to 80 horse-power to swing the boom and operate the thrust. The hoist and swing motors are located in the car, Fig. 1, and are geared to the drums through suitable reducing gears. The thrust motor is mounted directly on the boom, Fig. 2, and communicates its motion to the bucket staff through reducing gears connected to a pinion engaging a rack on the staff. The motors are of the crane or mill type, with high torque characteristic, and may be for either direct or alternating current. They are reversing and are under perfect control. When desired the controllers may be connected to the ordinary hand lever used on steam shovels, so that a steam shovel engineer can operate the electric shovel without any trouble. Data in regard to the sizes, capacities and motors required is given in Table I.

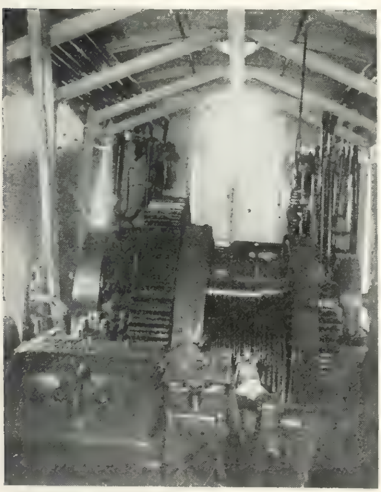


FIG. 1—INTERIOR OF CAB
Showing 200 horse-power hoist motor in foreground and automatic magnet control panels in rear.

The power is ordinarily taken from trolley wires, or from a transformer located near the cut, the feed cables from the power

circuit to the car being wound on a retractile reel in the cab and drawn in or paid out as the cut advances. The wiring in the car is enclosed in conduit, as may be seen in Fig. 1 and is well protected from moisture and mechanical injury.

The chief objection in the past to electrically operated shovels has been the possibility of damage to the hoist motor when stalled, due to the bucket digging in too deep, or striking a rock or other obstruction in the bank. The heavy current taken at such times was liable to cause a burn-out, while if the motor was properly protected by fuses or circuit-breakers, their continual opening caused annoying interruptions of service. This difficulty has been overcome by the use of automatic magnet switch control, which protects the motor against such overloads by cutting resistance into the circuit when the current exceeds a certain value.

A diagram of connections for such a method of control is shown in Fig. 3. The master controller has two running positions

TABLE I—ELECTRIC POWER SHOVELS

Weight of Shovels, Tons.	Size of Dipper, Cu. Yds.	Horse-Power of Motors		
		Hoist	Thrust	Swing
30	1	50	30	30
35	1¼	50	30	30
35	1¼	60	30	30
35	1¼	75	35	35
42	1½	75	30	30
65	2	100	35	35
95	3⅓	150	50	50
100	4	200	80	80

in either direction. The first position connects the motor to the line with all the armature resistance in series, the second position energizes magnet switches *VI*, *VII* and *VIII* through the accelerating relay *IX*. These switches short-circuit the resistance in sections, each successive step being delayed until the current in the accelerating relay falls below a fixed value. The various positions are interlocked, so that it is impossible for the switches to close in wrong order. The master controller can be thrown from full speed forward to full speed reverse, without damage to the motor, as the starting switches for either direction cannot close until all the control switches are opened and full armature resistance has been connected into the circuit. The reversal is thus made in the least possible time consistent with the safety of the motor.

In case of an overload on the motor, safety relay *X* opens,

breaking the control circuit of switches *VI*, *VII* and *VIII*, and cutting all the armature resistance into the circuit. The motor will then exert its full starting torque continuously until the overload is removed, when the resistance will be automatically short-circuited again. This feature of the control is especially valuable for shovel work, as frequently a stone or log may be dislodged by a steady pull when it cannot be moved by a sudden jerk. If the overload current exceeds the value for which the overload relay *XI* is set, the line switch *V* opens, disconnecting the motor from the line. On moving the master controller to the off position, magnet switch *V* is reset, and the motor may be started again in the usual way.

Where a more flexible control is desired a five point master controller is used. In this case, each of the switches which cut out armature resistance is controlled by a separate point on the master controller. The amount of resistance in the circuit is, therefore, under the constant control of the operator. At the same time the controller can be thrown immediately to the full speed position, and the motor will be automatically brought up to speed as rapidly as the accelerating relay will allow.

FIG. 2—80 HORSE-POWER, DIRECT-CURRENT THRUST MOTOR, MOUNTED ON BOOM

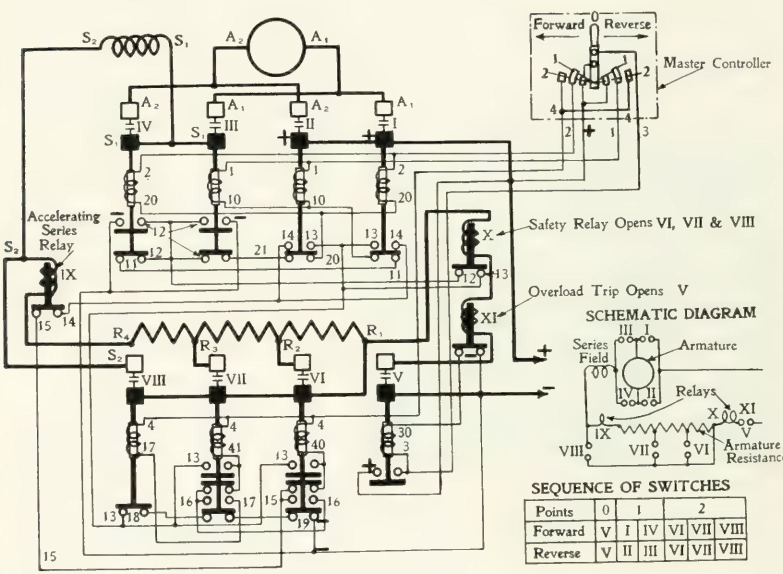
The motor driving the thrust may be operated either by a drum controller or by automatic magnet control. The motor and its controller must be of such a design that the motor will be able to develop a heavy torque for short intervals of time while standing still, or rotating very slowly. Its duty is to jam the dipper against the bank and hold it there while the hoist operates. As soon as the dipper strikes the bank the thrust motor ceases to revolve, except very slowly, but must still exert full torque in order to keep the dipper against the face of the cut. Its characteristics should, therefore, be such that it may be stalled frequently for a minute or more at a time and still keep developing full-load torque without injury.

The motor driving the swinging boom may be operated by hand control if provided with a magnetic brake to stop the motor quickly and keep the circuit-breaker from opening if the motor is re-

versed quickly; or may be operated by automatic control without a brake. The operator can place the bucket with greater precision and ease with the automatic control on account of the rapidity with which the magnets accelerate the motor. The controller panels and switches are placed in the rear of the car, while the master switches or drum type controllers are placed in the front within easy reach of the operator. This makes a very compact and accessible equipment.

OPERATING COSTS

While the initial cost of electric shovels is more than that of steam shovels, their operating cost is much less. They can ordi-



Points	0	1		2		
Forward	V	I	IV	VI	VII	VIII
Reverse	V	II	III	VI	VII	VIII

FIG. 3—DIAGRAM OF CONNECTIONS OF HOIST MOTOR AND AUTOMATIC CONTROL

narily be operated by a smaller number of men; the hauling of coal and water is dispensed with; their power economy is greatly superior to that of the steam shovels, and they can be handled with greater precision and rapidity. In addition the electric shovel is comparatively noiseless in operation, which is a great advantage for city use.

Some interesting data in regard to the cost of operation of electric shovels has been obtained by the Vulcan Steam Shovel Company, of Toledo, Ohio. One of these shovels, shown in Fig. 4.

has been operated by the Milwaukee Electric Railway & Light Company for several years, at a consumption of approximately 100 kw-hrs. per ten hour day. It is used for loading gravel at a gravel bank and is operated by two men, who load from 300 to 400 cu. yds. of gravel per day. The average daily expenses of operating this shovel are:—

One engineer	$2.00
One craneman	1.75
Electric power at 1.5c per kw-hr	1.50
Oil, waste, repairs, etc.	.75
Total	$6.00

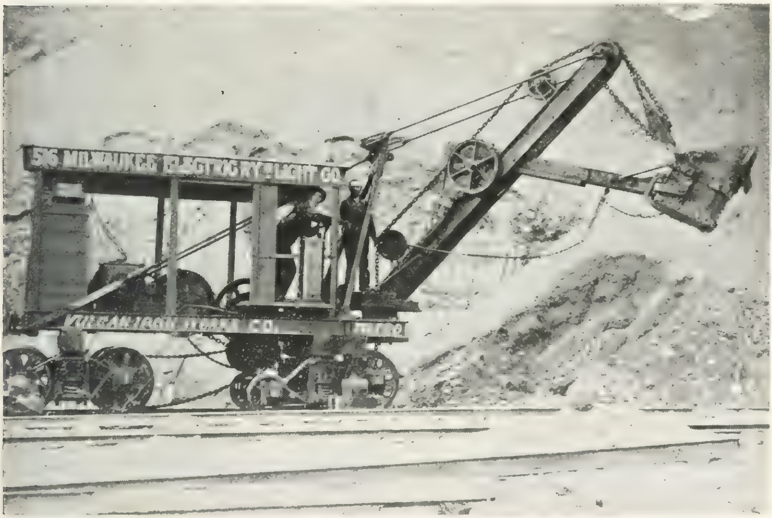


FIG 4—ELECTRIC SHOVEL OPERATED BY THE MILWAUKEE ELECTRIC RY. & LIGHT CO.

18-ton shovel, three-quarter cubic yard dipper, with two operators, shovels between 300 and 400 cu. yds. of gravel per day at a cost of less than two cents per cu. yd. Operating on 600 volt direct current. Current consumption 0.25 to 0.33 kw-hr. per cu. yd.

The Chautauqua Traction Company, of Jamestown, New York, has been operating a shovel similar to the one shown in Fig. 5, equipped with a 75 hp hoist motor, since 1907. This shovel is used in loading a mixture of gravel, sticky clay and sand, which is very hard to dig, and is operated by two men on the shovel and two pitmen. The current consumption on a special test averaged

163 kw-hrs. per eight hour day, and 534 cu. yds. of material were loaded in an average day. The total expenses per day, including the pitmen, were $8.80, or approximately one and two-thirds cents per cu. yd. The maximum capacity of this shovel is about 1 000 cu. yds. per eight hours. If operated at this capacity, the power consumption would be increased in proportion to the output, but the labor charges would be the same as figured in the above statement. This would bring the cost of shoveling down to about one cent per cu. yd.

The shovel shown in Fig. 6 has been in operation for some time

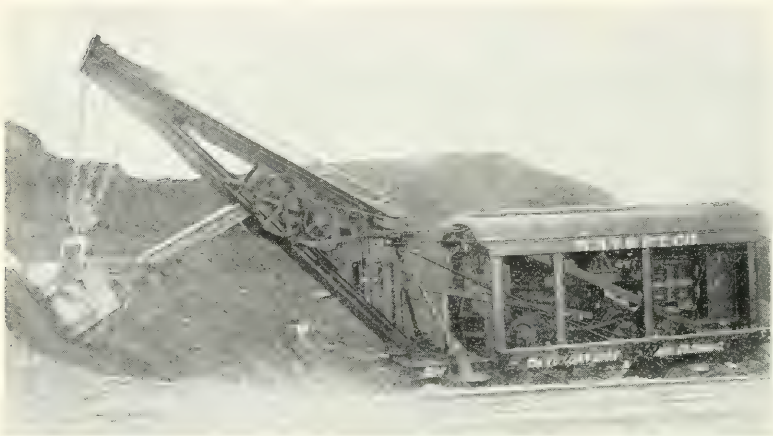


FIG. 5—ELECTRIC SCOOP OPERATED BY THE WESTERN NEW YORK AND PENNSYLVANIA TRACTION CO.

42-ton shovel, one and one-half cubic yard dipper, equipped with two 30 horse-power, and one 50 horse-power, 550 volt direct-current motors. This type of shovel ordinarily digs from 500 to 600 cu. yds. of gravel per day, at a cost of from 1.5 to 2c per cu. yd. Average current consumption, 0.3 kw-hr. per cu. yd.

loading blasted rock, alternating-current power being taken from the lines of the local central station. Data is not available concerning the cost of operating this shovel, but a shovel of similar motor and dipper capacity with extra high crane, used for the dredging of placer gold in Jackson County, Oregon, has a consumption of 0.5 kw-hr. per cu. yd. of ore handled. This shovel is run by alternating current, at 440 volts, three-phase, and receives power from neighboring transmission lines.

Perhaps the most promising field for electric shovels is in connection with electric traction lines. where electric power is usually

available at a very low rate. For this service they are mounted on standard gauge trucks equipped with air brakes, and may be hauled on the regular tracks, or may be equipped with a trolley and made self propelling, the maximum speed being about five miles per hour.

Great economy can also be effected by the use of electric shovels in any territory where coal is hard to procure and water power is comparatively cheap, as experience has shown that with current at two cents per kilowatt-hour or less, their cost of

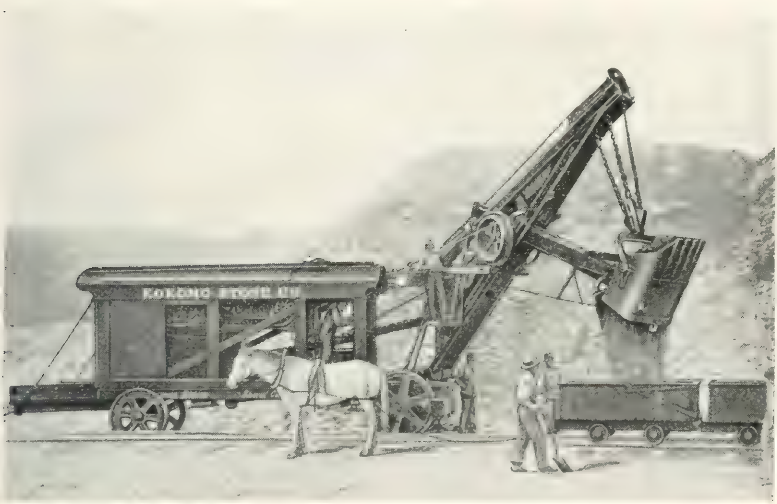


FIG. 6—ELECTRIC SHOVEL OPERATED BY THE KOKOMO STONE CO.

35-ton shovel, one and one-quarter cubic yard dipper, equipped with two 30 horse-power, and one 60 horse-power, 60-cycle, two-phase, 220 volt alternating-current motors. This type of shovel ordinarily digs from 400 to 500 cu. yds. per day of blasted rock or ore, and has a capacity of 600 cu. yds. per day. Average current consumption, 0.5 kw-hr. per cu. yd.

operation is only about half that of steam shovels. And as part of this saving is obtained by decreased labor costs, and the cost for power is only about one-third the total cost of operating the shovel, local circumstances may determine a saving at considerably higher power rates.

VOLTAGE REGULATION OF COMPOUND WOUND ROTARY CONVERTERS

JENS BACHE-WIIG

THE direct-current voltage of a rotary converter is directly dependent upon the alternating-current voltage of the circuit to which it is connected, there being a certain fixed ratio between the two. For a three-phase converter the alternating-current voltage is approximately 61 percent of the direct-current voltage; for a single-phase, two-phase, or six-phase diametrically connected converter the ratio is approximately 71 percent. This ratio is somewhat dependent upon the wave form of the machine and of the alternating-current circuit to which it is connected, as well as upon the setting of the brushes on the commutator, the above values being correct in case of a sine wave form and the brushes set on the no-load neutral position.

Assuming constant voltage at the alternating-current generator which serves as the source of power, the voltage of the alternating-current circuit at the converter is affected by the ohmic and reactive drops in the circuit. Therefore the direct-current voltage of the converter is dependent, within certain narrow limits, on the resistance and the reactance of the circuit between the alternating-current generator and the converter.

The ohmic and reactive drops in the circuit affecting the direct-current voltage are the drop in the line, in the transformers, in the choke coils if such are used, and in the converter itself. The ohmic drop in the line varies from a negligible amount, as in the case of a converter installed in the same building as the generator supplying the power, to approximately ten percent, the latter value not being exceeded in good practice. The reactive drop in the line may be due to either inductance or capacity. However, considering the rotary converter feeder circuit only and assuming normal conditions for electric railway operation, the drop in the line will ordinarily be an inductive drop and will be quite small. The ohmic and reactive drops in the transformers, in the choke coils and in the converter itself are of course dependent upon the inherent design of these parts and vary over a considerable range.

The effect of the combined ohmic resistance in the circuit is to lower the direct-current voltage of the converter, reducing it below the value determined by the alternating-current voltage at

the generator in the following way: If the direct-current voltage at no load is 100 percent, it will be lower at a given load by an amount equal to the ohmic drop at this load; e. g., if the ohmic drop is equal to ten percent of the normal voltage at full load, the direct-current voltage at full load will be 100—10=90 percent. Therefore, if a direct-current voltage of 100 percent is desired at full load, it is necessary to start with an impressed voltage at no load approximately equal to 110 percent. Considering the ohmic drop only, the voltage characteristic of the converter is always drooping.

Consider now the combined reactive drop in the circuit. While the word "drop" is generally used in this connection, the reactance may cause either an increase or a decrease in the direct-current voltage, depending upon the relative value of the armature ampere-turns and the field ampere-turns, or in other words depending upon whether the wattless current flowing in the machine is leading or lagging. In case it is leading, the effect of the reactance, as far as the wattless current is concerned, is to raise the resulting voltage, and in case it is lagging, the effect is to lower the resulting voltage. In the first case, the field ampere-turns are stronger than the amount required to obtain 100 percent power-factor; in the second case the field ampere-turns are weaker than those required for 100 percent power-factor. The effect of the reactance in conjunction with the energy component of the current is to produce a voltage drop bearing a 90 degree phase relation to the converter voltage. This effect can not be neglected as it has a considerable influence upon the voltage at the heavier loads in case of a relatively large reactance.

The combined effect of the ohmic resistance and the reactance in the circuit of a rotary converter are as follows:

1—Ohmic resistance times working current produces a voltage drop in phase with resulting converter voltage.

2—Ohmic resistance times wattless current produces a voltage drop at right angles to resulting converter voltage.

3—Reactance times working current produces a voltage drop at right angles to resulting converter voltage.

4—Reactance times wattless current produces a voltage drop (or rise) in phase with resulting converter voltage.

The effect of the ohmic resistance as considered in 2 is quite small and in ordinary cases can be neglected. The three remaining values only will be considered. In case of a lagging wattless current the influence of each of these three values upon the resulting voltage will be to lower it, whereas in the case of a leading wattless current, whether the resulting voltage will be higher or lower than the impressed voltage, will depend upon the relative strength of the ohmic and reactive drops. In case the wattless current is zero, i. e., the power-factor is 100 percent, the reactive drops are zero and the ohmic drop therefore will lower the resulting voltage.

As stated above, the wattless current flowing in the armature of the converter depends upon the relative strength of the armature and field ampere-turns; hence, it is dependent upon the excitation of the converter. To obtain 100 percent power-factor, a certain field excitation is required, determined by the inherent design of the machine. For any load condition within the range of the particular converter, the field strength can be so adjusted as to produce 100 percent power-factor at a certain load. At 100 percent power-factor, however, the wattless current is zero. Therefore, to obtain both 100 percent power-factor and a certain fixed converter voltage at a particular load, the impressed voltage at no load must be high enough to compensate for the ohmic drop at this load as well as for the drop caused by the product of reactance and working current. Furthermore, if the no-load voltage shall not be higher than the voltage desired at a certain load, i. e., if a drooping voltage characteristic shall be avoided, then it is necessary to have a certain amount of lagging wattless current at no-load, so as to reduce the converter voltage. This again means, however, that the power-factor will be low at no-load; any wattless current will necessarily reduce the power-factor at no-load on account of the small amount of watt (power) current flowing. For even a flat voltage characteristic, it is necessary that the power-factor of the converter at no-load be low; this has no serious objection, however, since with the small total current drawn at this load, it does not impose any additional requirements upon the system supplying the power.

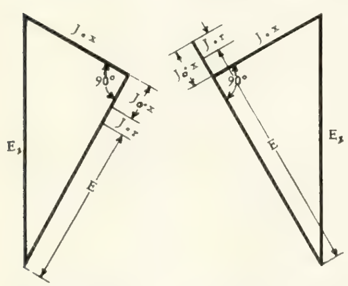
The proper way to operate a compound wound rotary converter to obtain a flat or slightly rising voltage characteristic is therefore to so adjust the shunt field rheostat that a lagging cur-

rent is produced at no load and to adjust the series field so that sufficient series ampere-turns are produced as the load comes on to make the sum of these ampere-turns and the constant shunt field ampere-turns produce unity power-factor at the average load. The fields may be adjusted so that this power-factor will occur at half or full load or at any other desired point on the load curve. It will be shown in the following that for normal operating conditions and with the fields properly adjusted, the power-factor will be nearly unity over a considerable range of load, which of course is desirable from an operating point of view. To keep it at unity over the entire range of operation, i. e., from no load to, say, 50 percent overload, would mean that the ohmic drop must be practically zero, or that the impressed voltage must be raised as the load comes on; the first condition is an impossibility and the second requires some form of adjustable voltage converter, the consideration of which is beyond the scope of the present article.*

In order to predetermine the voltage characteristic of a compound wound rotary converter, the total amount of reactance and resistance in the converter circuit must be known. Furthermore, the ratio of the series field ampere-turns to the armature ampere-turns should be known. With this information the voltages and power-factors of a converter for a certain setting of the field rheostat can be closely approximated, as illustrated in the following example:—The armature ampere-turns at full load are considered as 100 percent; the shunt ampere-turns required to give 100 percent power-factor at no load and normal voltage are assumed to be 100 percent of the armature ampere-turns; the series field ampere-turns at full load are assumed to be equal to 50 percent of the armature ampere-turns; the ohmic drop at full-load current and 100 percent power-factor is assumed to be ten percent and the corresponding reactive drop 25 percent. Assuming, furthermore, that a power-factor of 100 percent is desired at one-half normal load and that the voltage obtained at no load under the assumed conditions is to be 100 percent; then, the setting of the shunt field rheostat has to be such that the sum of the series and shunt field ampere-turns at half load is 100 percent, i. e., the field rheostat must be set to give 75 percent shunt ampere-turns at no load, the series ampere-turns at half

*See "Voltage Variation in Rotary Converters," by Mr. F. D. Newbury, in the JOURNAL for Nov., 1908, p. 616, and editorial, p. 615.

load giving 25 percent (50 percent of 50), or a total of 100 percent ampere-turns at half load. As in any synchronous machine, the wattless component of the armature current is determined by the difference between total field ampere-turns required to give 100 percent power-facor and field ampere-turns supplied. Hence at no-load, with the shunt field ampere-turns reduced to 75 percent of the value required to give 100 percent power-factor and the relative strengths of the field and armature ampere-turns as assumed above, the wattless component is 100—75=25 percent of the normal current. This current sets up a reactive drop equal to 25 percent of 25 percent=6.25 percent volts, 25 percent being the reactive drop at full load current. This drop is in phase with the impressed voltage. The working current is zero, neglecting the losses, so that the reactive drop is zero. The constant line voltage to be applied is therefore approximately equal to 106.25 percent volts. The power-factor at no-load, assuming four percent loss in the converter, is approximately: $\text{P-F} = \frac{4}{\sqrt{25^2 + 4^2}} =$ 16 percent, 25 being the percentage of wattless current in the converter at no-load.



Wattless Current Lagging. Wattless Current Leading.

FIGS. 1 AND 2—VECTOR DIAGRAMS SHOWING COMPONENTS OF VOLTAGE DROP IN ROTARY CONVERTER

At one-fourth load, the voltage can be determined as follows: The working current is 25 percent and sets up a reactive drop at right angles to the resulting converter voltage equal to 25 percent of 25 percent reactance = 6.25 percent volts. The wattless current is equal to 100 percent — (75 percent, shunt + 25 percent of 50 percent, series) = 12.5 percent amperes. This produces a reactive drop in phase with the converter voltage equal to 12.5 percent of 25 percent reactance = 3.125 percent volts. The voltage is *reduced* by this amount as the current is lagging. The ohmic drop is equal to 25 percent of 10 percent = 2.5 percent. Adding these voltages in their proper phase relation gives the resulting converter voltage as shown in Figs. 1 and 2. E_1 = impressed voltage, E = resulting converter voltage, J = working current J_0 = wattless current, x = total reactance and r = total resistance. Fig. 1 shows the sum of the voltages for a lagging wattless current and Fig. 2 similarly for a leading current. In the case just consid-

ered the wattless current is lagging, and accordingly Fig. 1 is to be used, with $E_1 = 106.25$ percent volts. Then $E = \sqrt{E_1^2 - (J.x)^2} - (J_0.x + J.r)$ or, substituting known values, $E = \sqrt{106.25^2 - 6.25^2} - (3.125 + 2.5) = 100.4$ percent volts, the approximate resulting voltage at one-fourth load.

The effect of the reactive drop at right angles has in this case little or no influence upon the resulting voltage on account of the small amount of working current. The power-factor is approximately $P\text{-}F = \frac{25 + 6.5}{\sqrt{(25 + 6.5)^2 + 12.5^2}} = 93$ percent, with the losses increased about in proportion to the ohmic drop. The working current is 25 percent of full load current and the wattless current 12.5 percent.

At one-half load, using the same method, the following results are obtained: Working current = 50 percent; reactive drop at right angles = 12.5 percent volts; wattless current = zero; reactive drop in phase with the converter voltage = zero; ohmic drop = 5 percent; resulting voltage = 100.5 percent; power-factor = 100 percent. At full load the results are: Resulting voltage = 99.7 percent volts; power-factor = 98 percent; At one and one-half load: Resulting voltage = 96.6 percent; power-factor = 96 percent. In the two latter cases, the wattless current is leading, i. e., the resulting voltage is determined according to Fig. 2; thus, the reactive drop in phase with the resulting voltage tends to increase it.

It is obvious that the above method does not give exact results. Starting at a certain point on the saturation curve corresponding to 100 percent volts and arriving at another voltage lower or higher than the first, is bound to change the wattless current due to change in the shunt excitation. This again changes the reactive drops. Furthermore the saturation curve is not a straight line, which introduces another variable factor; the leakage changes with change in load and the reactance does not change in proportion with the current, but follows another curve. The effect of the saturation curve upon the shunt excitation can easily be compensated for, but the corrections for other factors are more difficult. However, the operating conditions and other factors are equally approximate. The voltage is more or less variable, because in most cases rotary converters derive their power from distribution systems having generating stations operating in parallel and supplying power to sub-stations; the ter-

minal voltage of the converter is accordingly dependent on other factors than its load. Furthermore, the total amount of reactance and resistance in the converter circuit is necessarily more or less of an approximation. It is thus apparent that an approximation is all that is possible or necessary and that the above method will give satisfactory results.

As regards the amount of series field chosen in the above example, it might be stated that a great number of converters

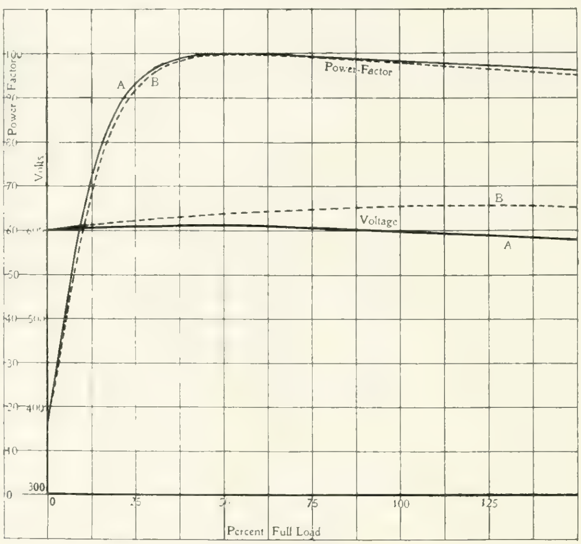


FIG. 3—POWER-FACTOR AND VOLTAGE CURVES OF ROTARY CONVERTER

A-A—50 percent series field; 25 percent reactance; 10 percent resistance; 100 percent power-factor at half load.

B-B—60 percent series field; 25 percent reactance; 5 percent resistance; 100 percent power-factor at half load.

operating on railway loads are designed with just about this proportion between the series field ampere-turns and armature ampere-turns. On the other hand, the amount of reactance and resistance chosen are both unusually large. In case of a different series field strength or where unity power-factor is desired at other than half load, as well as in cases where the reactance and resistance of the converter circuit have different values than those assumed in the example, the proportions will change and the voltage characteristic will be different. However, by insert-

ing the proper values in each specific case and proceeding as outlined above, sufficiently accurate values will be obtained in all commercial cases. A few cases are shown in Figs. 3, 4, 5 and 6, the values for the resulting voltages and power-factors being plotted in ratio to the load. These are based on certain fixed values of resistance and reactance in the converter circuit, on a certain fixed load at which unity power-factor is desired, and on a certain fixed value for the resulting voltage at no load. The

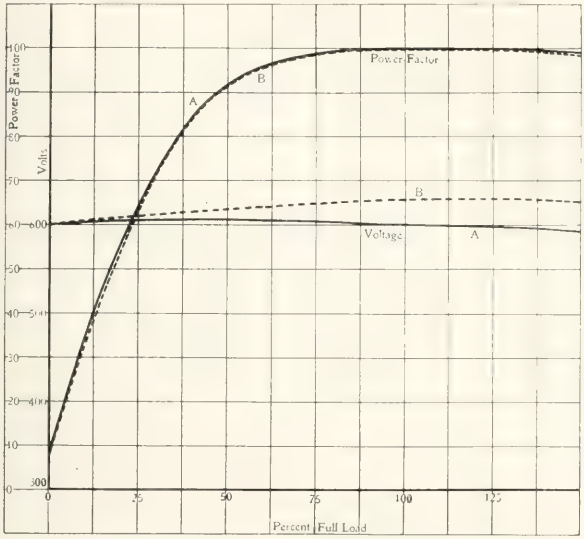


FIG. 4—POWER-FACTOR AND VOLTAGE CURVES OF ROTARY CONVERTER

A-A—50 percent series field; 25 percent reactance; 10 percent resistance; 100 percent power-factor at full load.

B-B—50 percent series field; 25 percent reactance; 5 percent resistance; 100 percent power-factor at full load.

values were obtained by the method described above. In plotting these curves, 100 percent voltage has been made equal to 600 volts, this being a standard operating voltage for rotary converters.

In each case, one figure shows two sets of curves giving approximate values of voltages and power-factors to be expected at loads between zero and 50 percent overload. This is the ordinary load range for rotary converters, although they usually are

called upon to carry considerably higher momentary loads. In all cases the series field ampere-turns are assumed to be 50 percent of the full load armature ampere-turns. Curves *AA*, Fig. 3, represent conditions based on the assumption of 25 percent reactance, ten percent ohmic drop and 100 percent power-factor at full load, which is the case cited above. Curves *BB*, Fig. 3, are worked out on a basis of five percent ohmic drop. It will be noted that while the voltage characteristic is affected by the difference in the ohmic drops, the power-factors are almost the same. As

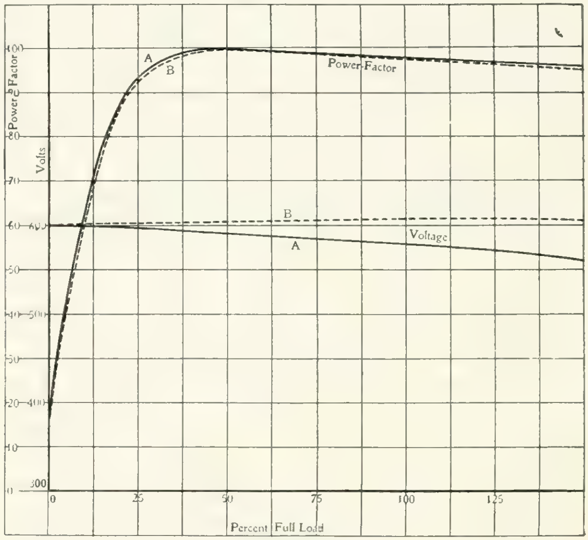


FIG. 5—POWER-FACTOR AND VOLTAGE CURVES OF ROTARY CONVERTER

A-A—50 percent series field; 15 percent reactance; 10 percent resistance; 100 percent power-factor at half load.

B-B—50 percent series field; 15 percent reactance; 5 percent resistance; 100 percent power-factor at half load.

regards the amounts of ohmic drop chosen, it may be noted that while ten percent represents a maximum, five percent on the other hand is a value which usually is encountered, and it is difficult to obtain a percentage drop that is much below this value when the alternating-current source of power involves a transmission circuit. Fig. 4 represents the same conditions except that 100 percent power-factor is obtained at full load. This condition, as compared with the case of Fig. 3, shows lower power-factors at the lower loads and a flatter voltage characteristic, the differ-

ence being caused by the greater wattless current at no load.

The curves of Figs. 5 and 6 are plotted in a similar manner except that here 15 percent reactance is assumed. By comparing Figs. 3 and 5, and 4 and 6, respectively, the effect of the greater reactance will be observed at once. A total reactance of 15 percent might be said to be the minimum required in the converter circuit in order to obtain an approximately flat voltage characteristic. Assuming a reactance of five percent in the converter itself, it thus requires approximately 10 percent additional reactance

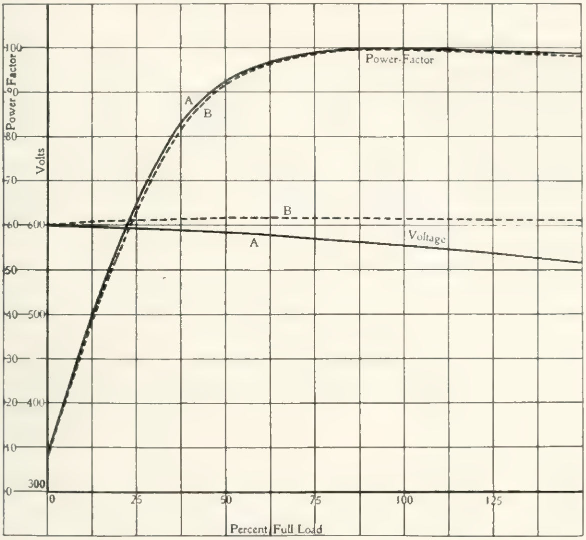


FIG. 6—POWER-FACTOR AND VOLTAGE CURVES OF ROTARY CONVERTER

A-A—50 percent series field; 15 percent reactance; 10 percent resistance; 100 percent power-factor at full load.

B-B—50 percent series field; 15 percent reactance; 5 percent resistance; 100 percent power-factor at full load.

in the transformers and choke coils to fulfill this requirement. This is the reason that at least one of the large manufacturers of rotary converters in this country has established the standard practice of allowing for ten percent reactance in the transformers, thereby saving, whenever possible, the extra expense and space required for installing special choke coils. There are cases, of course, where choke coils have to be employed, and where no other arrangement can be made there is no particular objection to their being installed.

SQUIRREL CAGE INDUCTION MOTORS WITH HIGH RESISTANCE SECONDARIES

RUDOLFH E. HELLMUND

THE use of squirrel cage induction motors with high resistance secondaries is becoming more and more common for certain classes of service, and it is therefore proposed to discuss some features to be considered in connection with their application. Motors of this type are employed in three distinct conditions of service:—

1—For operation in combination with a fly-wheel, driving machines which are subject to heavy loads of short duration, such as punch presses, etc.

2—For driving machines which require comparatively large starting torque, either on account of large friction of rest or on account of large masses to be accelerated.

3—For application where a large starting current is objectionable.

PURPOSES AND ADVANTAGES OF HIGH RESISTANCE SECONDARY IN COMBINATION WITH FLY-WHEEL

The reason for applying high resistance end rings in the case first mentioned will be evident from the following consideration:— If the torque required for a certain operation is very large but of short duration, while the driven machine is running light for the larger part of the time and requires only a very small torque, the working conditions are very poor for an induction motor of normal design operating without a fly-wheel. In such a case the motor must be large enough to carry the heaviest load, while it will run most of the time with only a very small part of this load. Any motor, however, operating at a small percentage of its full-load capacity, has a poor efficiency and low power-factor. Under certain conditions, it is, therefore, more economical to supply a fly-wheel in which energy is stored while the load is off, and which gives out energy when the load comes on. Since this action reduces the peak loads, a smaller motor can frequently be used. Moreover, the load on the motor is more uniform, since not only are its peak loads decreased, but its low loads are increased by the amount of energy stored in the fly-wheel during the periods of low loads. By obtaining a more uniform load the all-day power-factor may be materially improved, and, if the conditions are

properly chosen, the all-day efficiency may be increased. It is evident that the more uniform load will be favorable for the line and the power station and that the limitation of heavy peak loads is advantageous for the motor from a mechanical point of view, because the purely mechanical strains on the shaft, brackets and frame as well as the strains on the coils caused by the electromagnetic action, are thereby materially reduced.

The possible advantages which can be secured by the use of a fly-wheel may be summarized as follows:—Reduction in size of motor; improved power-factor; improved efficiency; equalization of line load; reduction of mechanical stresses.

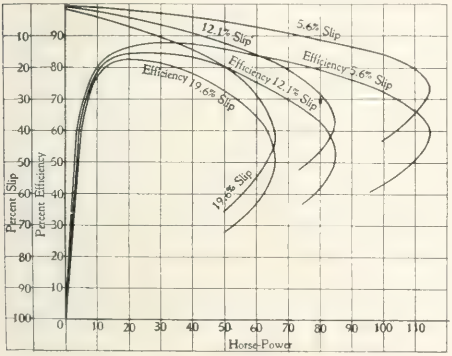


FIG. 1—EFFICIENCY AND SLIP CURVES OF A 50 HP SQUIRREL-CAGE INDUCTION MOTOR IN TERMS OF THE OUTPUT FOR THREE DIFFERENT VALUES OF FULL-LOAD SLIP

Additional energy can be stored in a moving mass only by increasing its speed and when so stored can be utilized only by allowing the speed to decrease. The factors which determine the amount of energy that can thus be stored or utilized are the amount of change in speed and the mass of the rotating parts. If, therefore, the mass is not large compared with the work to be done, it is necessary to have a large change in speed in order to accomplish a certain result; in other words, a type of motor must be employed which possesses the characteristic of changing speed considerably with changes in load. In a squirrel cage induction motor this characteristic may be obtained by designing the secondary with high resistance, whereby a large slip, i. e., a large change in speed, is obtained. In the case of wound secondary induction motors the same result is accomplished by inserting external resistance in the secondary circuit. In the case of direct-current motors the desired speed variation is usually obtained by heavy compounding.

All of the above facts are well-known.* They are reviewed

*See paper on "Function of Flywheels in connection with Electrically-Operated Rolling Mills," by Mr. H. C. Specht, *Trans. A. I. E. E.*, 1909, p. 869.

here in order to bring out the fundamental facts more clearly. Mention has been made of the methods employed with the wound secondary induction motor and the direct-current motor, because these types—especially the direct-current—have been used so frequently with fly-wheels and because by referring to these types, the peculiarities of the squirrel cage motor may be well illustrated.

INDUCTION MOTOR PERFORMANCE AS INFLUENCED BY INCREASED SLIP

Before considering further the application of squirrel cage motors in connection with fly-wheels it may also be advisable to recapitulate the more important of the inherent characteristics of this type of motor, as designed for this purpose. Increased secondary resistance, by means of which increased speed variation (i. e., increased slip) is obtained, results in increased losses. Increased losses in turn mean decreased motor efficiency. In other words, the efficiency for a given motor load will decrease as the slip increases. The amount by which the efficiency is affected may easily be determined since each percent increase in slip is equivalent to approximately one percent decrease in efficiency. Assume, for instance, a motor which has a full-load efficiency of 85 percent. If the slip of this motor is increased by four percent, the full-load efficiency drops to about 81 percent. For other loads than full-load the effect of the increased slip may be calculated in an equally simple manner, since within the limits of no-load and 25 percent overload the increase of slip caused by a certain increase of resistance is practically proportional to the load. Efficiency curves for a 50 hp motor at 5.6, 12.1 and 19.6 percent full-load slip are shown in Fig. 1. The same curves in terms of torque are shown in Fig. 2.

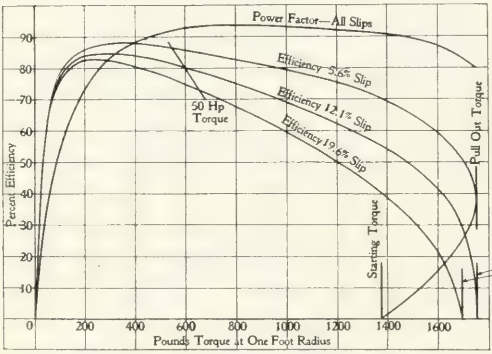


FIG. 2—EFFICIENCY AND POWER-FACTOR CURVES OF A 50 HP SQUIRREL-CAGE MOTOR IN TERMS OF TORQUE FOR THREE DIFFERENT VALUES OF FULL-LOAD SLIP

Squirrel cage and wound secondary motors are alike with respect to the change in efficiency with secondary resistance. The wound secondary motor, has, however, a possible advantage over the squirrel cage motor, in that, with the former it is possible to vary the secondary resistance and reduce it to a minimum whenever it is not required for speed variation. This means that the reduction in efficiency caused by the speed variation characteristic is not necessarily permanent, but need exist only part of the time. The direct-current motor has the advantage over both types of induction motors inasmuch as with it the desired speed variation is obtained without materially increasing the losses.

For a given torque the power-factor of an induction motor is affected but slightly by the slip, as shown by the power-factor curve of Fig. 2, which corresponds to all three slip values under consideration. Since, however, with a given torque the horse-power output of the motor decreases with increased slip, the power-factor curves corresponding to the three values of slip, although having approximately the same maximum value, are shifted against each other if plotted in terms of the horse-power output as shown in Fig. 3. It will be seen, moreover, that while the power-factor increases slightly with the increased slip for all loads below 125 percent of full-load, this increase is very small; so small, in most cases, that it need hardly be considered.

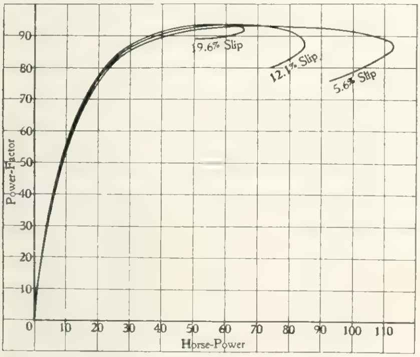


FIG. 3—POWER-FACTOR CURVES OF A 50 HP SQUIRREL-CAGE MOTOR FOR THREE DIFFERENT VALUES OF FULL-LOAD SLIP

The maximum torque is practically not affected by increasing the slip up to a certain value, as may be seen by reference to the 5.6 and 12.1 percent slip curves of Fig. 2, which reach the same maximum torque values. On the other hand, if the maximum torque is expressed in terms of the full-load torque, as is frequently done, the value of the full-load torque must also be considered. Assuming several speed curves of a motor, given by the use of end rings of different resistance corresponding, for example, to five, ten and fifteen percent slip; if the horse-power values for

these respective slips are to remain the same, it is obvious that different values of torque must be considered, as the torque increases in the same percentage as the slip. In other words, the value of the full-load or rated horse-power torque is different for each speed curve. Therefore, the ratio between maximum torque and full-load torque decreases by the same percentage as the full-load speed, while the absolute value of the maximum torque remains unchanged. If the slip is increased above a certain value, the maximum torque obtainable with practical conditions of operation decreases in its absolute value and becomes equal to the starting torque. This may be seen from the 19.6 percent curve of Fig. 2.* The maximum output of a given motor in horse-power, in contradistinction to the maximum torque, always decreases with increased slip, as is evident from the curves of Figs. 1 and 3, since, even though the torque values remain the same within certain limits, the speed of the motor decreases.

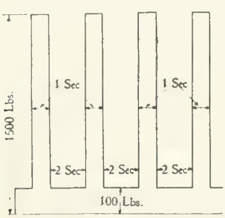


FIG. 4—LOAD DIAGRAM

All of the above considerations are based on the assumption that the primary winding remains unchanged. By modifying the conditions on the primary side of the machine the above relations may be materially altered, except that it is impossible to obtain increased slip without correspondingly increased losses in the secondary. This latter fact is of utmost importance in every application of squirrel cage motors with high resistance secondaries, not only because the efficiency is less but also because the increased losses are dissipated in the motor itself and thus affect its temperature rise. This means that increasing the slip above certain limits will decrease the rating of a given frame.

FULL LOAD SLIP FOR VARIOUS APPLICATIONS OF FLY-WHEELS

The most suitable design of motor for a given fly-wheel application can, of course, be determined only by considering all features involved therein. Nevertheless it will be possible here to indicate the general principles by discussing some typical cases which represent closely average conditions in practice, both with regard to motor design and the applications themselves.

Consider, for example, a driven machine with a load diagram as shown in Fig. 4. The 50 hp motor, the characteristic curves

*See also curves A and E, Fig. 7.

of which are shown in Figs. 1, 2 and 3, has a maximum torque of only 1 750 lbs., which, under normal conditions of operation will not be sufficient to carry the peak load, since, with a considerable drop of potential in the line, its maximum torque may easily drop below 1 500 lbs. It will therefore be necessary to employ a 75 hp motor of similar design. Such a motor will have an efficiency of about 68 percent at 100 lbs. torque. It will have a power-factor of about 43 percent at 100 lbs. torque and 93 percent for the 1 500 lbs. torque. Since the torque values apply about twice as long for the low torque as for the high, the all-day efficiency will be about 72 percent and the all-day power-factor about 60 percent. If a fly-wheel is used which, with a slip of 5.6 percent at 50 hp, will reduce the maximum load on the motor to 1 200 lbs. and increase the minimum load value to about 300 lbs., the 50 hp motor will be quite sufficient to do the work, since the square root of the mean square value of the load is only slightly above 50 hp and the maximum torque required from the motor is well within its capacity. On account of the full load slip of 5.6 percent, which is larger than the usual slip of a motor of this size, the heating of the secondary will be noticeably increased and the heating of the primary will be increased slightly. With the motor under consideration both heating values will be within safe operating limits, since the standard motor is designed for rather large overloads. From the 5.6 percent slip curve in Fig. 2, it will be seen that the efficiency is 87.5 percent for 300 lbs. torque and 70 percent for the 1 200 lbs. torque, which means that the all-day efficiency is well above 82 percent as compared with 72 for the 75 hp motor without fly-wheel. From the power-factor curve it may be seen that the all-day power-factor is above 85 percent against 68 in the case of the 75 hp motor without fly-wheel. The load variations on the line have been reduced from 90 to 75 percent and the maximum load on the line as well as the strains on the motor have been reduced to about 80 percent of the value which would apply to the 75 hp motor without fly-wheel. It follows, therefore, that the use of a fly-wheel with a motor having 5.6 percent full-load slip is an advantageous arrangement.

Consider now the same case of application under the assumption of 19.6 percent speed variation between no load and a load of 50 hp, this being a value which could be used to good advantage in connection with a direct-current compound-wound motor. The load on the motor in this case will be more nearly uniform, as a re-

sult of which the square root of the mean square load value will be slightly smaller than in the previous case. The increase of the slip and of the corresponding losses in the secondary are now, however, of such magnitude that dangerous heating will result if the 50 hp motor is used. It will be necessary, therefore, to use a 75 hp frame. The all-day efficiency of this motor for a load only slightly varying from 50 hp will be about 74 percent, a value which is lower than that for the 75 hp motor without fly-wheel, as well as for the 50 hp motor with 5.6 percent slip. The all-day power-factor will be about 89 percent, a value which, although better than for the 75 hp motor without fly-wheel, does not represent a material improvement over the one obtained with the 50 hp motor and a 5.6 percent slip. The load variation on the line and the maximum loads and stresses in the motor are of course further reduced as compared with the 50 hp motor with 5.6 percent slip. However, since the values obtained with 5.6 percent slip are safely within the limits of normal performance of the motor and fairly satisfactory for a line of machines of the capacities usually coming into consideration, these latter advantages obtainable with 19.6 percent slip usually will be of no practical value. The attempt to apply a large speed variation means, in this case, the sacrifice of the two main advantages which may be obtained with a smaller value of speed variation, i. e., a smaller motor investment and better efficiency, while it brings practically no advantage over those obtainable with the smaller speed variation. A slip of seven to eight percent would probably give the best results in this case of application. The load variations would be reduced more than with 5.6 percent slip; the frame size would be the same; the all-day efficiency would be nearly the same, and the all-day power-factor would be somewhat higher as compared with the motor with 5.6 percent slip.

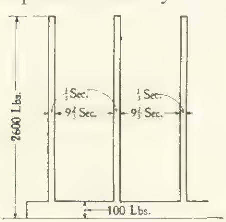


FIG. 5—LOAD DIAGRAM

In the above case, both the maximum and minimum loads are of rather short duration. Consider, now, a case where the maximum load is of short duration and the minimum load of a longer duration, as indicated by Fig. 5. The square root of the mean square value of the load is again approximately 50 hp, but without a fly-wheel it will require a motor of about 100 hp to carry the

maximum loads. In this case, assume a fly-wheel which will reduce the maximum load to 1 100 lbs. with 12.1 percent slip at 50 hp. The minimum load will not be altered in this case since the intervals between the peaks are so long that the fly-wheel will always be speeded up to the motor speed corresponding to 100 lbs. torque before the next peak load occurs. The efficiency of the 50 hp motor in this case will vary between 80 and 66 percent, but since the high load calling for the low efficiency of 66 percent is on only a small portion of the time, the all-day efficiency will be well above 75 percent. The efficiency of a 100 hp motor without fly-wheel will be about 68 percent for 100 lbs. torque and 80 percent for 2 600 lbs. Since the higher load of 2 600 lbs., calling for the better efficiency value, is on only a very short time, the all-day efficiency will be below 73 percent. In the same way it may be concluded that the all-day power-factor of the 50 hp motor with 12.1 percent slip will be above 80 percent while that of the 100 hp motor without fly-wheel will be below 60 percent. It appears that in this case of application good results may be obtained with as high a slip as 12.1 percent, if the losses caused by this slip are not too high to cause an overheating of the motor. This of course depends largely upon the design, and in case the motor does not have large overload capacity for normal slip values, the heating probably will be too high with the load under consideration. It may be concluded, therefore, that for this case of application a slip of about 11 to 13 percent will be satisfactory with a 50 hp motor of liberal design, while with a 50 hp motor more closely rated, a smaller slip should be chosen.

It is evident then that in cases where the intervals between the peak loads are even larger than in the above case, slips above 12 percent may give good results; but it may be safely concluded that the speed variation of an induction motor should generally be smaller than that of a compound direct-current motor under otherwise similar conditions. This of course means that the equalizing of load which can economically be done with a certain fly-wheel is not as large with a high resistance induction motor as with a direct-current compound motor. As an advantage, however, the induction motor does not require as uniform a load as is desirable for a direct-current motor. If the load of a direct-current motor varies continuously from say 40 percent to 160 percent of full-load, the life of the commutator is considerably reduced, unless the commutation of the motor is exceptionally good.

An induction motor that is mechanically well designed will carry a load of this character continuously without the least difficulty. It shold be considered, moreover, that for moderate capacities, induction motors of the squirrel cage type are usually used, while slip ring motors are used for large capacity requirements.

Attention should further be called to the following facts:— While, for a given application an induction motor may best be designed for ten percent full-load speed regulation (slip), whereas a direct-current motor with 20 percent full-load speed regulation would be used to better advantage, this does not mean that with a given fly-wheel the equalizing effect of the induction motor is only half that of the direct-current motor. This may be seen by considering the speed-torque curves of Fig. 6, both of which correspond to a speed reduction at full-load of 12.1 percent; one of these applies for an induction motor, while the other applies for a compound wound direct-current motor. If, for instance, it is assumed that there is a load variation of from 40 percent to 160 percent of full-load, the speed variation of the induction motor between these loads is 16.5 percent, while that of the direct-current motor is 12.2 percent. This difference always exists and is due to the fact that, referred to the 100 percent ordinate, the speed-torque curve of the induction motor is inherently concave while that of the direct-current motor is convex.

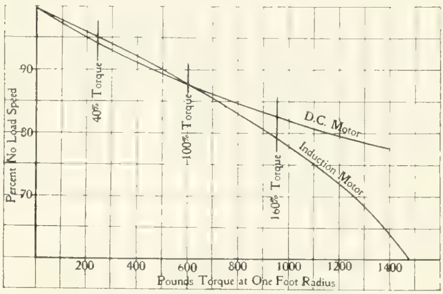


FIG. 6—COMPARISON OF THE SPEED-TORQUE CURVE OF AN INDUCTION MOTOR AND THAT OF A DIRECT-CURRENT COMPOUND-WOUND MOTOR

CASES IN WHICH HIGH RESISTANCE SECONDARIES AND FLY-WHEELS SHOULD NOT BE USED

In the cases so far considered, the duration of the peak loads is sufficiently short to make it possible to reduce them with a fly-wheel of reasonable proportions and such full-load slip values as are economical in connection with induction motors. If the duration of the peak loads is longer than above indicated, there are cases in which the use of a fly-wheel would be advantageous in connection with a direct-current motor while its use in con-

nection with squirrel cage motors is not advisable, unless considerations of uniform line load are of such importance that sacrifices in motor cost and efficiency are justified.

If the conditions are such that the maximum load is not more than about 150 percent of the square root of the mean square load value and the minimum load not less than one-fourth of this value, then an induction motor without fly-wheel may be used to fairly good advantage as compared with the direct-current motor. In cases involving peak loads of long duration, which are three to four times the square root of the mean square value, it may be advisable to use a wound secondary motor with external resistance and possibly automatic slip regulation, if the motor is large enough to justify one or both of these complications. In cases of small capacities it is quite often the best plan to use a squirrel cage motor large enough to carry the maximum load, for, while the all-day efficiency and power-factor of such motors are not high, the absence of undue complications offsets this objection.

HIGH RESISTANCE SECONDARIES FOR SEVERE STARTING CONDITIONS

Distinction should be made between two different cases of severe starting conditions, viz., cases in which high starting torque is required on account of a large friction or working resistance in the driven machine; and cases in which a high starting torque is required on account of large masses to be accelerated.

In the first of these two cases only the torque during the first moment of the starting period is of importance and the torque required at this moment is fixed by the driven machine in combination with a certain allowance for a possible drop of potential in the line. Usually squirrel cage motors are started with an auto-transformer, giving a reduced voltage at the motor during the starting period. Since the starting torque of the motor varies approximately with the square of the starting voltage, it may be adjusted within wide limits without changing anything at the motor, by simply varying the starting voltage. With a motor of normal design, the highest possible starting voltage usually means a large starting current and since the electro-magnetic stresses and vibrations in the windings caused thereby are proportional to the square of the current, too high a starting voltage will have a harmful effect upon the winding. It has, therefore, become customary to limit the starting voltage to 60 to 75 percent of full vol-

tage in large motors, and 75 to 85 percent in motors of medium size, while full voltage is used with small motors

If, after adopting the starting voltage which is considered to be consistent with good practice for a given motor, the starting torque is not sufficient for the driven machine, the torque can be increased within certain limits by increasing the secondary resistance and consequently the slip of the motor. Curve *E*, Fig. 7, shows the amount of the starting torque for the 50 hp motor already discussed, for various values of slip and full voltage. Since all values of this curve for any given reduction in voltage decrease in the same proportion, it is characteristic for any fixed starting voltage. The curve shows that up to a certain slip value, in this case about six percent, the starting torque increases in proportion to the slip. With higher slip, the starting torque increases more slowly and above a certain value, about nine percent in this case, but little may be gained by increasing the slip. An increase of the slip beyond about 13 percent means a decrease in starting torque.

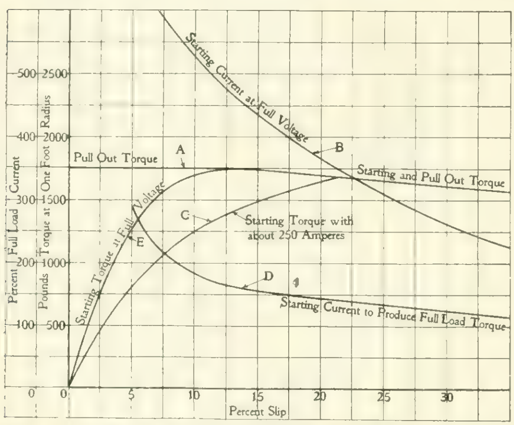


FIG. 7—CURVES SHOWING THE STARTING TORQUE, PULL-OUT TORQUE AND THE STARTING CURRENT OF A 50 HP SQUIRREL-CAGE MOTOR IN TERMS OF THE FULL-LOAD SLIP

It might be concluded that it would not be good practice in this case to use a slip of more than six to seven percent; this is slightly altered, however, by the fact that with increased slip and a fixed potential the starting current in the motor decreases as shown by curve *B*, Fig. 7. Since this current determines the dangerous stresses in the motor, it is therefore evident that with increased slip the admissable starting voltage increases. If it is assumed that a safe current in this motor is about 250 amperes, corresponding to three and one-half to four times full-load current, and that the starting voltage is raised to a sufficient value to get this current value, the curve *C* in Fig. 7, is obtained. From this curve it appears that, up to the slip which gives the limiting current value at full voltage, any increase in slip gives

an improved starting torque. But while the curve is fairly steep up to eight percent slip, it is rather flat above this value. This indicates that the gain in starting torque is rather small if the slip is increased above a certain value. Moreover, if the motor is to carry its rated load continuously, it will hardly run within safe heating limits with more than seven to ten percent slip, the exact amount depending upon its design. If the motor has only an intermittent load a slip up to 17 percent may be suitable, but in no case of application can much be gained by increasing the slip above this value. If the starting torque obtained with that value of slip which is the limit with regard to safe heating of the motor, is not sufficient for starting the load, it is frequently possible to obtain the desired result by designing the motor with a stronger field. This of course means a change of the primary winding and certain reductions in power-factor, but is generally the cheapest way to obtain the desired result, since the only other alternative with the squirrel cage type of motor is the use of a larger motor frame.

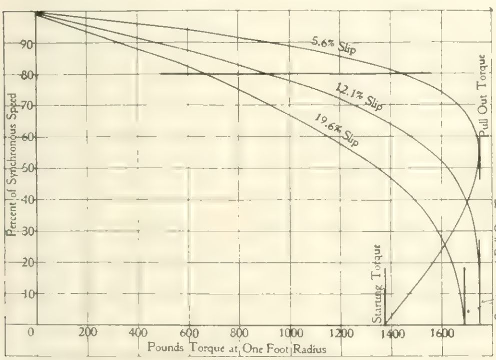


FIG. 8—SPEED-TORQUE CURVES OF A 50 HP SQUIRREL-CAGE MOTOR FOR THREE VALUES OF FULL-LOAD SLIP

Whenever the starting conditions are severe because large masses have to be accelerated, the starting torque at the first moment is not of such importance as the average torque over the whole starting period. If the time in which the machine must be brought up to speed were the only consideration, the slip value giving the highest average torque during acceleration would be the best value to be chosen. In Fig. 8 are shown the speed-torque curves for the 50 hp motor for the same three full-load slip values previously considered. In order to get a fair comparison between the three curves, the average torque values have been determined between 0 and 80.4 percent speed, the latter obviously being the highest obtainable with a slip of 19.6 percent. The following values are obtained:—

Average torque for 5.6 percent full-load slip, 1630 lbs.
Average torque for 12.1 percent full-load slip, 1585 lbs.
Average torque for 19.6 percent full-load slip, 1516 lbs.

Increasing the slip further will decrease the average torque. If the slip is decreased considerably below 5.6 percent the average torque will also be decreased. It follows, therefore, that a slip of five to six percent will give the quickest acceleration.

As a rule rapid acceleration is not of prime importance but the heating of the motor is again the deciding factor. The problem is, therefore, to adopt a slip value which, for a given cycle of starting and running, results in a minimum amount of heating, i. e., minimum losses in the motor. It is at once obvious that the heating in the motor during the running period increases with the full-load slip. During the starting period, conditions are not quite as simple and can be studied in detail only by rather lengthy calculations.* The following consideration will, however, demonstrate the general principle. Under the assumption of equal starting voltage, the average current during the starting period will be smaller the larger the slip. This is obvious since the current gradually decreases from the starting current values shown by curve *B*, Fig. 7, to the full-load current. Since the losses are proportional to the square of the current, there is a tendency for increased losses with decreased slip. This is, however, counterbalanced in two ways; first, a decreased slip means less resistance in the secondary, which partially counterbalances the effect of the increased currents; second, above a certain minimum value, decrease of slip means quicker acceleration and, therefore, a short starting period. Accordingly, it appears that, even if the starting period is considered, the larger slip does not always give the best heating conditions. If the starting and running periods are considered in combination, it will usually be found that a comparatively low slip value, generally below six to eight percent, will give the best results.

The above considerations are again somewhat modified by the fact that, with regard to the safety of the motor, it is possible to use somewhat higher starting potentials with increased slip. But even if this is taken into account the most favorable slip value is hardly ever above eight to ten percent. Moreover, it is

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*For method of calculation see discussion by the author on "The Heating of Induction Motors," *Trans. A. I. E. E.*, 1909, pp. 554-6. See also article on "Multispeed Squirrel-Cage Induction Motor," *Electrical World*, Oct. 13, 1910, p. 865.

frequently necessary to keep the starting current in the line within certain limits.

HIGH RESISTANCE SECONDARIES FOR REDUCING STARTING CURRENT

In considering cases in which a low starting current is of prime importance and in which high resistance rings are chiefly adopted for this purpose, a distinction should be made between two different cases:—

1—Small motors to be started with full line voltage.

2—Motors to be started with a starting compensator.

For the first case curve *B*, Fig. 7, is typical and shows that for an increase of slip a fair gain in starting current may be effected. Hence, it may be advantageous to use slip values as large as permissible with regard to heating and efficiency. In certain applications for intermittent service and where efficiency is of minor importance, the practical slip values may therefore be rather high.

For cases in which a starting compensator is used curve *D*, Fig. 7, is typical and shows the starting current in the line which results from reducing the starting voltage so as to give for each slip value a given fixed torque (in this case full-load torque). By increasing the slip up to a certain value, about ten percent, the reduction in current is considerable for a given increase in slip, while the gain is only very small by any further increase. If in addition to this fact, the heating caused by the increased slip is taken into account, it follows, as for most conditions previously discussed, that it is not practical to use too large slip values.

CO-OPERATION IN DEVELOPING THE INDUSTRIAL MOTOR FIELD

HARRY G. GLASS

THE electric motor is applied in two distinct fields. One of these is the operation of large manufacturing plants and industries of various kinds, in which a number of motors replace engine drive. The other may be termed the use of motors by the general public. The latter service is wide and diversified; it is being extended to include many who are already small power users, and many who have not used mechanical power, but could do so with great advantage. While the large factory usually has engineers or managers who are well versed in power apparatus and readily appreciate the advantages of electric drive, on the other hand the general public is not familiar with electric power applications. Electricity is still a mystery and there is a general reluctance to introducing the new methods or new appliances which may be efficiently adopted in connection with electric power. Obviously the introduction of the electric motor into general use for miscellaneous purposes presents new problems and requires new methods. It is a combined engineering and commercial problem, the successful outcome of which depends upon good apparatus and sound engineering in the application of the motors, and also upon an effective and convincing presentation of the economies and advantages of electric service.

Three parties are interested; the consumer, the central station which supplies power, and the manufacturer who furnishes the electrical apparatus. It naturally falls to the lot of the central station to develop its business by demonstrating and convincing the public of the advantages of electric service. The manufacturer is also vitally concerned in the success of this work, and is in position to co-operate with the central station, both by commercial assistance, and more particularly by bringing to the central station a fund of engineering knowledge which is not otherwise available and which is of fundamental importance. The means by which the manufacturer and the central station may efficiently co-operate in advancing the general use of electric power from central station circuits is well worthy of careful examination, as activity of this kind marks one of the notable advances in the extension of electric service.

The consuming public represents the real field for electrical

development. That part of the public who are using electricity for various services must be taught to extend its use; that part who are using other forms of energy must be converted to the greater economy and conveniences of electric service; that part of the public who are still practicing the most primitive methods of labor and existence must be educated to a higher plane of productiveness and comfort. To accomplish all this is the chief mission of the central station lighting and power industry and of the electrical manufacturer.

From the beginning the lighting feature of the central station industry has been its chief and often its sole dependence. The recent advent of new illuminants of such high efficiency as to almost revolutionize the industry, and the ever increasing exaction of the customer, have placed the fixed charges, as compared to the gross income, upon a less favorable basis, and hence the necessity of creating a load during non-lighting hours that will reduce the ratio of fixed charges to gross income. To accomplish this, electric service must be forced into a field already occupied by motive power, which though less efficient, yet through habit and misconception of the advantages of electric service commends itself to the user. Because of these conditions, the new and progressive work of the central station is strictly educational in character, and begins right at this point.

In prosecuting this power-load development work the individual central station company may have a few power customers to whom to refer, and references may also be made to installations of motor drive, which have been made by nearby companies, but at best the field for comparisons is very limited. On the other hand, the representative of the manufacturer is one of many associate salesmen, who interchange valuable experiences and data that become the common knowledge of each. A wide-awake engineering salesman of a great manufacturing company thus has information at his ready command to make a strong appeal to the self-interest of any prospect, because every one is interested in the methods of others and the more analogous the application, the stronger the appeal. Comparison with some successful competitor, process or product with which he is familiar, is the quickest way to secure the interest of a prospective customer. Some of the manufacturers of electrical apparatus are annually spending large sums gathering, classifying and otherwise outlining a vast amount of useful information applying to the application of electric drive to various indus-

tries. This information affords a substantial engineering basis for friendly co-operation with central station companies in securing new business.

Assuming the foregoing conclusions as representative of existing conditions, how can the interested parties work to the best advantage and what are some of the direct benefits to each, resulting from such co-operation?

As the central station is the party directly interested in the sale of energy, it devolves upon its representatives to inform the prospect concerning rates, reliability of service and results obtained from the use of electric power in similar installations, and the salesman of the manufacturer when he comes in contact with the same prospect, should confirm by every influence and fact at his command, the position of the central station representative. Team work affords the strongest commercial effort. Each salesman deals specifically with matters concerning the proposed installation, with which his experience lends familiarity and authority. Objections are successfully answered; valuable suggestions are offered; a power contract is executed, or else the prospect is induced to assign the true reason for not doing so, and thus future efforts may be conducted upon lines of least resistance. Many prospects are incapable of prompt decision, hence the advantage of weakening the resistance at each and every attack.

The central station solicitor brings to his support the many strong arguments favoring purchased power. These arguments are often ineffective, because the element of self-interest causes the prospect to doubt the salesman's sincerity. It is to the interest of the solicitor to sell power. Hence the plausibility of his best arguments are weakened, as the prospect considers him prejudiced in favor of central station service. The position of the apparatus salesman is strengthened with the prospect, simply because he is in position to sell an isolated plant, if he really considered this the proper installation for the customer to make.

Very few central stations employ solicitors who have had engineering training, and as practically all salesmen representing the leading manufacturers of electrical apparatus have had such theoretical and practical training, the direct assistance will be immediately apparent, and the indirect help of an educational nature obtained by the central station solicitors as each proposition is handled in the field, is certain to strengthen the efficiency of the new business department.

The time has arrived for the central station manager and the manufacturer to realize that the interests of each are identical, and the opposition encountered by each is also identical, viz.: ignorance of the efficiency of the use of electrical energy. Many instances showing the advisability of such co-operation could be cited, but one experience with which the writer is familiar will suffice. A certain manufacturer, wishing to try out this method, secured an experienced man familiar with central station practice, to take up the work in one of its district offices. This man picked out one of the progressive central stations in this field and laid the plan before the management, the plan being, briefly, that the central station should supply motors to its customers and distribute the data on motor applications prepared by the manufacturer, to the present and prospective users in its field; the local solicitors should call on the salesman for help in working up any proposed installations, and the salesman should keep in close touch with the solicitors, and turn in any information relative to prospective installations which he might secure. For a time this plan was not adopted, mainly for the reason that the central station did not wish to sell motors unless absolutely necessary. This difficulty was successfully overcome by making satisfactory arrangements by which dealers in different parts of the territory would handle such sales as they could and the central station would supply only such motors as, owing to size or special conditions, the dealers could not handle.

Soon after the arrangement was made, the manufacturer found it necessary to detail a representative exclusively to this territory. The solicitors of the local company soon discovered the immense value of the salesman's help, for within one year the number of horse-power in motors installed increased over 100 percent. The benefits in increased business, however, did not accrue solely to the central station, as the manufacturer who had the foresight to advance the co-operative policy, secured the orders for a considerable proportion of the new apparatus required, as well as two 3 000 kw turbo-generators. The representative of the manufacturer is now looked upon as being of more assistance to this company than any one member of its own new business organization.

TEXTILE TYPE MOTORS

ALBERT WALTON

AS the French say: "Perfection is made up of trifles but perfection is not a trifle." It is the little things that determine success or failure and the difference between success and failure is generally a matter of details. Nowhere has this been better exemplified than in the development of a satisfactory motor for individual drive on machines in textile mills. In many respects the textile motor is like any good induction motor with a squirrel cage secondary. In fact it is a refinement of the standard motor to meet the added requirements of textile mill service.

Briefly, these requirements are a greater steadiness in speed, perfect protection from dust, and a liberal rating as to horsepower, combined with especially good electrical characteristics. The conditions determining these requirements, as detailed in the following pages, go to show that the textile type motor must be super-excellent in every respect. It is like demanding of a man that he be not only an all-round athlete with record-breaking capabilities, but that he be also a polished gentleman and a finished scholar of great erudition.

The most casual observer would notice that lint or "fly" as it is called, is prevalent in the air of a textile mill. It forces itself on one's attention by collecting on the face and clothes and in the passages to the lungs. And as it is breathed in by the people in the room, so it follows every mechanical draft in every flue, duct or passageway, not excepting those that may have been placed designedly in a motor for ventilating purposes.

But like all matter carried by the air in suspension, it is subject to influences which cause it to deposit on any convenient surface or available pocket. Obviously, therefore, the textile type motor must be of such structure that it will present only such surfaces for deposit of lint as are readily accessible, and will have no pockets for a continued reception of the little particles. In other words the system of ventilating ducts used in standard motors cannot be employed successfully here. If dependence is placed on currents of air for cooling, it will soon be found that the motor is heating more and more on the same or a lessening load. Investigation shows each duct effectually plugged with a felt-like pad of slowly accumulated fibres which, unfortunately,

not only stops the cooling air currents, but provides a non-conducting substance which in effect wraps that part in a heat retaining blanket. It were better that the ducts be filled with iron, for this material will at least conduct the heat to the surface where it can be radiated to the air. This, in fact, has been the solution of the cooling problem. All ducts have been eliminated and the motor has been made large enough to run cool by radiation only. Such a design is made more feasible by the small losses incident to the good performance demanded.

The motor is not entirely enclosed, as this has been found neither necessary nor advisable. The revolving element, however, has been made solid with no projecting parts and, as no air is to be forced through the windings, the coils are completely and closely covered by rugged end-bells. The whole exterior presents a smooth surface from which the accumulation of dust is as easily removed as from the most accessible part of the machine it drives. This arrangement provides a motor that will be as cool running a year from the day of installation as at the end of its first week of operation. A cardinal principle, therefore, in textile motor design, is to depend on radiation only and build the motors accordingly.

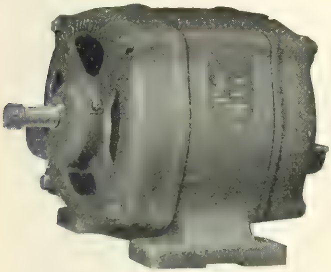


FIG. 1 ONE HP TEXTILE TYPE LOOM MOTOR

But fly makes trouble in another way also, at the bearings, which is not less important than the difficulties mentioned. So insidious and omnipresent is the lint that it will find its way wherever an opening is left for it. Add to this the fact that a cotton fibre has the same propensity for adhering to an oily surface that a hair has to a wet surface, and it takes little foresight to see the fate of a bearing that is not entirely dust-proof. The writer has seen a long light tuft of cotton gently wafted against the projecting end of a shaft, instantly caught up and, by a combination of capillary and centrifugal forces, caused to wipe the oil from the reservoir and distribute it about the room; an hour was sufficient to cause a hot box. The textile type motor has dust-proof bearing housings. The bearing is of the ring oiling type and has a bronze bushing so inserted in the cast iron housing that the rings cannot get out of place, no matter what the position of the motor. It is, therefore, never necessary to inspect the bearing to see if it is

running, and no opening has been left for that purpose. In fact the very act of raising a dust-covered lid above a ring to look down upon it is apt to be the cause of its stopping, for a few fibres are liable to drop from the lid on to the ring. Thus the inspection which shows the ring running successfully is liable to leave it stuck fast and a hot bearing in progress of rapid development.

There should, therefore, be no opening in the bearing above the oil ring. The necessary slot in the casting for the insertion of the ring should be closed securely by a cap screwed in place. A liberal opening should be left, however, for filling the well and for inspection of the oil level, and this should have a lid so arranged that it cannot be left open. There should be no unnecessary openings in the housing, and under no circumstances any openings or threaded joints below the oil level. It is always difficult to make a threaded joint tight to oil. And the location and service in which these motors are used demands that every precaution be taken to prevent any possibility of leakage. So well has this demand been met that, under ordinary working conditions, a bearing of the textile type will easily run 90 days without re-oiling or inspection of any sort. Old oil is removed when the machine is given its annual overhauling. An automobile oil-syringe is found to be very handy for the work and afterwards for cleaning the box with kerosene.

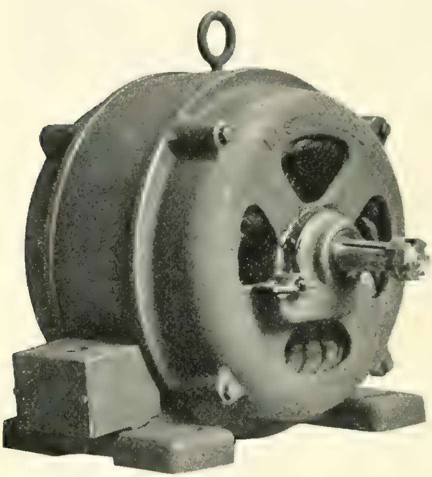


FIG. 2—FIVE HP TEXTILE TYPE SPINNING FRAME MOTOR

Steadiness in speed has been mentioned as a prime requisite in textile machinery. The textile mill demands and expects to get uniformity of speed which, in other factories, is considered beyond the most remote of dreams, and it is important that it be secured. Handling tender yarns is a delicate process at best. When a quarter million strands are being spun and another quarter million woven simultaneously it becomes an engineering wonder. For a hundred years competition has been keen between the

various builders of textile machinery and in the mills themselves, and some of the most marvelous products of human ingenuity are the results. But while they give calculated results if run at their proper speed they give proportionately less if the speed is not right. Not only does this apply to the hourly averages of rates of speed as shown by a speed counter for periods of a minute or 30 seconds, but it is even more true when the fluctuations occur at intervals too short to be detected by ordinary means. In fact for a given speed variation the shorter the intervals during which the speed change takes place the worse for the product. Such changes are most detrimental when they assume the form of regular impulses from piston strokes at the engine or from belt lacings passing over pulleys. Accordingly when placing the motor directly upon the machine it is important to use a motor of low "slip" and good speed regulation It is customary, therefore, for spinning frame work to wind the motor with a slip of about three percent from no load to full load. As the power required to drive a spinning frame does not vary 30 percent the variation in speed will be well within one percent if the frequency of the current be maintained at constant value, as is obtainable with turbo-generators as the source of power. It is this feature which has made the application of electric motors to textile machinery a success and that has resulted in a very notable increase in production through their use.

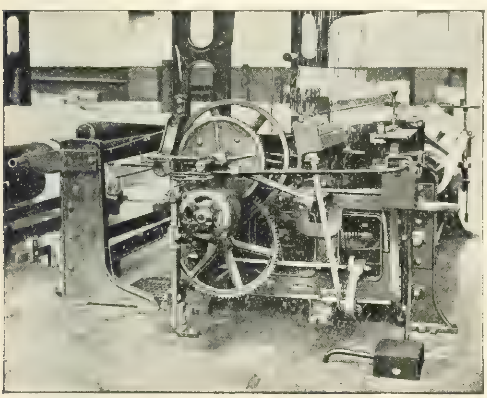


FIG. 3—ONE HP TEXTILE TYPE MOTOR DRIVING SILK LOOM

But the best mechanical design obtainable will produce nothing but disappointment and failure if the motor is not conservatively rated, and designed with a full knowledge of the requirements of the machine that it is to drive. Textile mill service is continuous from 7 a. m. to 6 p. m., and the rooms have to be hot and moist to work the fibres to their best advantage. With high temperature, high humidity and unremitting load the motor is working under a disadvantage even without considering the dust

and lint. Furthermore, it is undesirable that the motor run at a high temperature not only because this means rather hot insulation and a shortened motor life but because such hot motors radiate heat that is sensible and detrimental to the operatives. The less efficient belt drive actually liberates more heat in the room but it is so diffused as to be felt only as warmer room atmosphere. On the contrary, a small motor improperly rated and operated at a high temperature radiates heat that is oppressive even though the number of heat units be actually less, as the motors are placed on the working levels where this radiated heat is felt in its full effect. While this is not a serious matter owing to the isolation of the motors in an alley where work is not called for, it is considered good practice to use motors which will run considerably below their guaranteed temperatures, thus removing the only possible objection the operatives themselves could have to the motors. While this means larger motors, any other policy is short-sighted and indefensible.

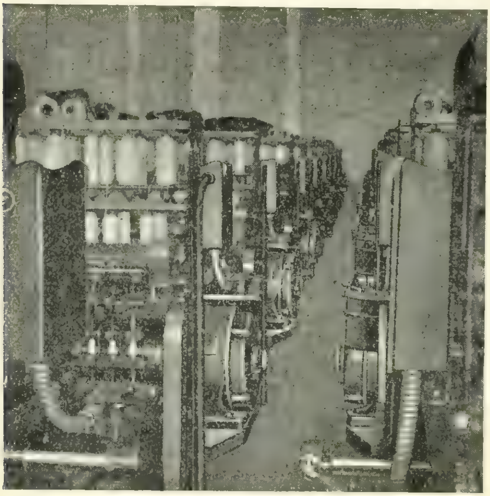


FIG. 4—FIVE HP TEXTILE TYPE MOTORS DRIVING SPINNING FRAMES

When it is realized that textile mills frequently require more power in normal operation than the peak load of the central station of a good-sized city and that this load is steady at this value for ten solid hours, an idea will have been formed as to the desirability of reducing coal bills by even a small percent. To this end, motors of unusually high efficiency have been produced for the work. The service to be rendered is known precisely and it has been possible to distribute iron and copper in the motor so as to work the material to the best advantage for the speed and range of load involved. The design of each motor was based on a definite load instead of on an average condition, and better results were therefore possible. This point will be better appreciated when

it is considered that standard motors must be designed to meet general conditions which vary over wide ranges, as in driving wood-working machinery or machine tools, etc. As a result, in every instance, an increase in efficiency of one or two percent has been effected so that in many of the more important sizes the motor losses are actually not over ten to 12.5 percent, a remarkable achievement in the design of motors of five to 7.5 horse-power. It is partly by this reduction of losses that the lower temperature has been maintained.

Although power-factor is of less importance than efficiency, in that it does not directly affect the coal pile, it has nevertheless been given its due weight, and in all but the smallest sizes of motors has been maintained at approximately 90 percent at full-load, in some instances considerably exceeding this value. It was early decided that if within reasonable limits one percent in efficiency could be gained by a sacrifice of two percent in power-factor, a net gain would be secured by the purchaser, and the two characteristics have been evaluated in this ratio wherever they have come in conflict. Excellent power-factor and efficiency are not difficult to obtain but can be given their due value as assets only when other qualities are considered; chief among these are starting torque and clearance.

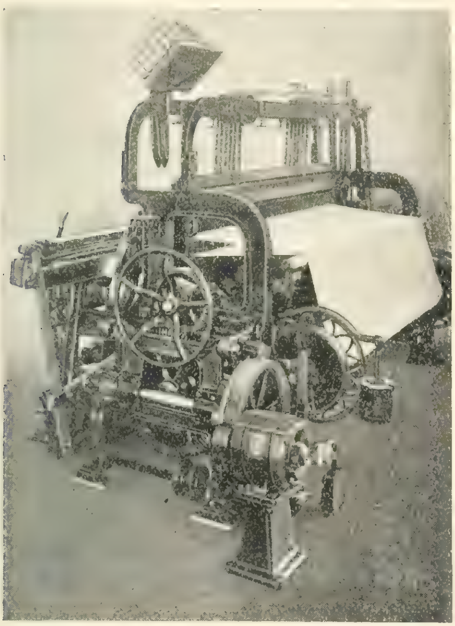


FIG. 5—ONE HP TEXTILE TYPE MOTOR GEARED TO CROMPTON & KNOWLES BROAD WORSTED LOOM

However excellently a motor may run and however small its losses, it is of little value if it will not start the machine to which it is rigidly connected. If the requisite starting torque be not provided for in the design the motor is as useless as an automobile engine with a broken starting crank, for there is no way

to supply the deficiency. A spinning frame, for example, requires over twice the torque to start that it does for continuous running. To secure a motor of 85 percent efficiency with a starting torque of 1.5 times full-load torque is vastly different from securing the same efficiency and power-factor with a starting torque of 2.25 times full load. It is not sufficient to rearrange the windings in the same frame. An entirely new motor is needed with a new frame and different punchings. The service is peculiar and special designs are required to meet it. For example, while a 12 horse-power pull may be required to start a machine on a Monday morning, this excessive requirement lasts but ten seconds and cannot be allowed to affect the 56-hour running efficiency under a five horse-power load. Both characteristics must exist in the same motor.

It is also essential that the motors be made so rugged as to require little or no expert attendance. One of the principal factors making this possible is a liberal clearance between stationary and rotating elements. The mechanical designer desires to make this clearance as large as possible. The electrical designer desires to make it small. Its length is always a vital point, and in textile work, where hundreds of motors of one size are installed, this feature should be given as much consideration as electrical performance.

Nothing but failure can come in the electrical development of an industry when the electrical designers attempt to change customs, habits and practices to suit their motors. Thus for other large power consumers, such as steel mills, cement mills, railways, etc., the industries have been closely studied and motors built to meet their requirements. As mill customs are practically fixed by usage, necessity and efficiency, the motor must be changed to meet the conditions. The gratifying reception that is being given to the textile type motor is only one more link in the chain of evidence proving that this is the underlying principle of successful application of motors to any large industry.

WINDING OF DYNAMO-ELECTRIC MACHINES—VI

LARGE DIRECT-CURRENT MACHINES

FROM the standpoint of the armature winder, the building of a large direct-current armature is not a particularly complicated operation. In contrast to the smaller sized machines, which may be subjected to all sorts of abuses, the large direct-current generator or motor is nearly always installed in a clean and dry location, is under continual observation, and is frequently inspected in detail and thoroughly cleaned. Thus, although the insulation throughout is rendered moisture and oil proof by repeated dippings or coats of varnish, no such elaborate precautions are ordinarily necessary to render the armature waterproof as are taken in the case of industrial and railway type motors, and it can be of a much more open construction, with correspondingly better ventilation. On the other hand the centrifugal strains are liable to be higher, and the windings musts be very carefully braced to protect them from the magnetic strains produced by heavy short-circuits, to which they are much more susceptible then the smaller machines, on account of the very low resistance of the electrical circuits to which they are connected.

It is a curious anomoly that a large part of the direct-current output of both railway and central station power plants is generated originally in alternating-current units. The large sized engine driven direct-current generator is thus becoming the exception rather than the rule for modern installations, while rotary converters and motor-generator sets of large capacity are being used to a correspondingly greater extent.

The design of these various types differs in many particulars. With respect to the purely mechanical features of the winding process, however, they are essentially similar, and will be so considered in this article.

THE CORE

On large sized armatures, the methods of core assembly used with the smaller sizes become entirely impracticable. The laminated core is seldom over one foot in depth, while the armature is sometimes 20 feet or more in diameter. It is evidently not feasible to punch the laminations in one piece of this size. In armatures beyond a certain diameter, they are consequently punched in sectors of the required depth, and two or three feet in length.

Dovetails are provided on the inner circumference of each sector, which fit into corresponding slots in the spider arms, as shown in Fig. 93, and hold the core together. The punchings are assembled with the joints in the successive layers staggered to provide a more continuous magnetic circuit, and greater mechanical stability. They are japanned on both sides to reduce eddy current losses. In addition, when extra insulation is required, sheets of waxed paper, punched to the same shape as the laminations, are inserted between them at regular intervals.

Vent-plates are inserted at suitable intervals throughout the core and finger plates are used at each side as supports for the teeth. These finger plates are cut into sectors, and provided with dovetails to correspond with the laminations. The end plates, which hold the core in position, are, however, of one solid ring of cast iron or steel. The core is compressed between these end plates by means of jack-screw equipments of the type shown in Fig. 94. Several of these are used at a time, the lower jaws being blocked up to serve as a support for the bottom of the frame. The core is retained in position by means of ring keys between the end plates and spider arms.

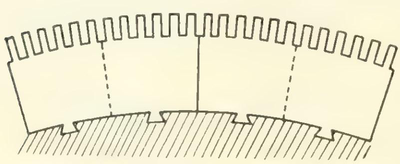


FIG. 93—ARRANGEMENT OF LAMINATIONS IN CORE

Before the core is ready for the windings, a steel straightening bar, of the same width as the coils plus the insulating cells, is driven into each slot. This serves to drive any projecting laminations back even with the teeth. A special calking chisel is then driven against the wedge grooves of the adjacent slots, forcing the teeth firmly against the straightening bar. The surface of the slots is thus made perfectly uniform. After all the slots have been gone over in this manner each one is finished on both sides with a special file of uniform width throughout its length. A wave shaped steel spring, laid against one side of the file and clamped in its handle, serves to press it against the side of the slot.

On most of the larger sized machines, the commutator center is an integral part of the armature spider. The commutator is thus assembled directly on the core instead of being assembled on a separate base and pressed onto the spider or shaft, as is nearly always done on the smaller machines. It is never as large in diameter as the core, and consequently copper necks are necessary to

connect the segments to the windings. These consist of two thin strips of copper, side by side, riveted and soldered to the commutator-bars at the lower end, and spread apart sufficiently at the upper end to contain the coil leads, and also occasionally the leads from the armature cross-connections. They are tinned and are riveted together just below the openings.

The spider may be mounted on a shaft before the armature is wound, for greater convenience during the winding and testing. This temporary shaft is removed before shipment, and, when the size permits, the armature is mounted on its permanent shaft at the works. The larger sized armatures, however, cannot be shipped

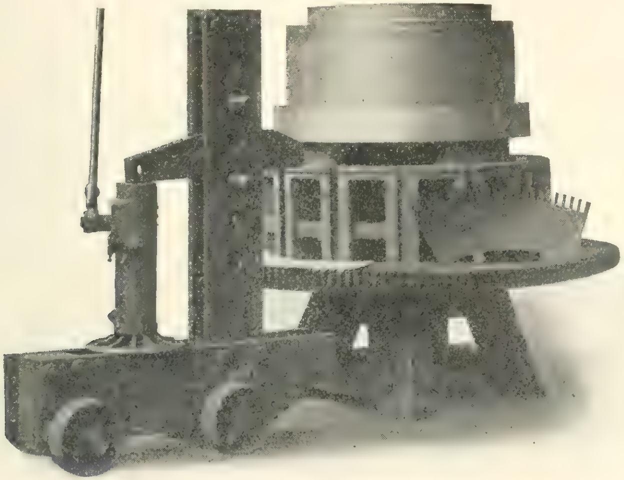


FIG. 94—ARMATURE CORE, PARTLY ASSEMBLED

mounted, and must be pressed on the shaft at the time of installation.

THE COILS

Nearly all coils for the larger sizes of machines are formed of bare copper strap. They are usually of the one piece, one turn diamond type, there being as many coils as there are commutator bars. To secure better space factor, however, and for other design and mechanical reasons, two or more single coils are bound together into a mechanical unit, the individual coils of which are insulated from one another and electrically separated, so that the number of slots is only a fraction of the number of bars.

The method of insulating this type of coil depends on the size, voltage and operating conditions of the machine, and on the

number of single coils composing a complete coil. When there are less than four single coils per complete coil, the ends of each single coil are taped with one layer of cotton tape, half overlapping. This taping extends a sufficient distance along the straight part to assure that the joint between it and the rest of the insulation will be well protected. The straight parts are then wrapped with a fish paper and mica wrapper, which is interwoven between the straps in such a manner as to furnish insulation between the single coils, and is then wrapped several times around the complete coil, the exact number of turns depending on the size, voltage and operating conditions of the machine.

When there are four or more single coils per complete coil, alternate single coils are wrapped with one turn of fish paper and mica, held in place by a non-overlapping layer of cotton tape. The single coils are then assembled and a cell of fish paper and mica wrapped over the whole. The coil is then taped with a layer of cotton tape, non-overlapping over the wrapper and half lapped over the ends. It is then brushed with, or dipped in black finishing varnish and air dried, after which it is dipped twice in insulating varnish and dried in an oven for twelve hours after each immersion. Before it is ready for use in the armature, the leads are cleaned of insulation and varnish and thoroughly tinned.

ARMATURE CROSS-CONNECTIONS

Nearly all direct-current machines of the larger sizes are wound with a lap or multiple circuit winding. This means that there are as many circuits through the winding as there are poles, each generating current under a separate pole, and all connected in parallel through the brushes. As it is practically impossible for the voltages generated in these circuits to be exactly equal, there is a tendency for short-circuit currents to flow through the windings and the brushes. These currents have a tendency to equalize the flux values under the poles so that equal voltages will be generated in all the circuits. However, their maximum effect is halfway between the poles, so that their magnitude is practically limited only by the resistance of the windings and brushes. These equalizing currents cause overheating of the conductors, and sparking at the brushes, and thus reduce the capacity of the machine.

By connecting together points of equal polarity on the different circuits by means of a special connection between the windings and the commutator, the short-circuit current is removed

from the brushes entirely. In addition it is alternating in character, and out of phase from the main current by a large angle, so that a comparatively small current serves to build up or cut down the magnetic fluxes under the various poles until approximately equal voltages are generated in all the armature circuits.

As originally used, the equalizing windings consisted of two or more rings of copper wire or strap, from which taps were led to equi-potential points on the windings. The present tendency, however, is to equalize at as many points as possible, and this can be best accomplished by a series of cross-connections.

A form of connection which lends itself readily to this purpose, and occupies very little space is shown at the rear of the armature in Fig. 95. It consists of a strap of copper, bent to an "S" shape at the center as shown in the illustration. The insulation is usually the same as that on the end connections of the armature coils. The leads are tinned, and are riveted and soldered to taps taken from the rear end of the coils. This form of connector is generally bound in place with heavy twine.

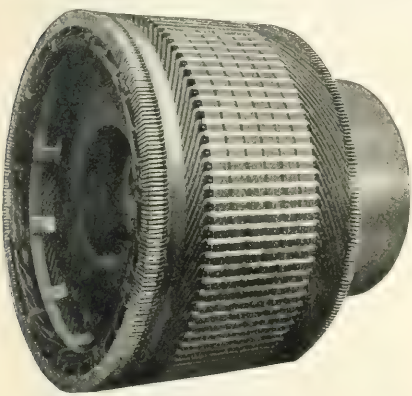


FIG. 95—ARMATURE OF 325 HP DIRECT-CURRENT MOTOR

An equalizing connector of the same shape as the diamond end of the armature coils is somewhat easier to install than the type shown above, and can be connected at shorter intervals; it is, therefore, very extensively used. The copper strap is bent edgewise into a flat loop, which is then pulled sideways into its finished form. Two or three of the connectors are generally bound together into a mechanical unit, using the same insulation that is used on the armature coil ends. The leads are brought out at suitable intervals and tinned.

This type of connector is frequently used at the front of the armature, where it rests on a special coil support. This support is insulated with fullerboard, and enclosed in a cell of drilling, part of which is laid back over the armature, as shown in Fig. 96, until the windings are completed. The leads are slipped into openings in the commutator necks at regular intervals, the top of

one connector going into the same neck with the bottom end of another, so that a number of complete rings are formed around the armature, with taps to the winding at similar points under each pole. Wooden wedges are driven between the necks, tight enough to force them into intimate contact with the leads, after which the leads are soldered into place, and the projecting ends are cut off close to the face of the necks. A test is then applied for short-circuit between adjacent connectors to be sure that the solder has not followed along the necks and short-circuited the commutator bars. The drilling is then folded back over the connectors, a band of fullerboard enclosed in a cell of friction cloth is wound over this, and the whole is finally bound in place by band

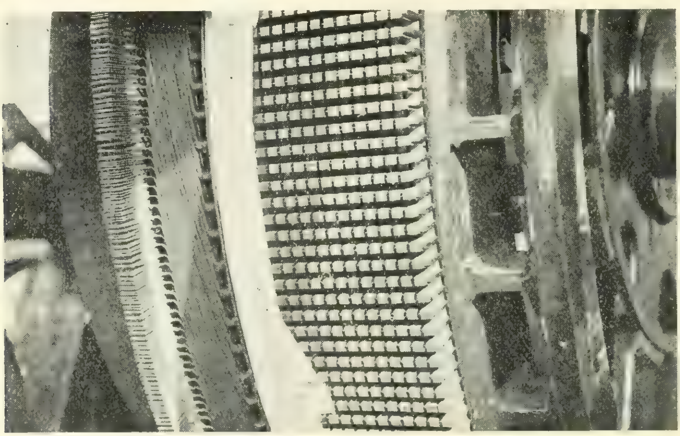


FIG. 96—DETAIL OF ARMATURE CROSS-CONNECTIONS, AT REAR OF COMMUTATOR OF 2 000 KW ROTARY CONVERTER

wires. The connectors are then tested for grounds. This test must be very carefully made at this time, as these connectors are covered by the main windings, and are difficult to repair after the latter are in place. Both types are used to considerable extent, depending on the characteristics of the machine.

Rotary converters are equalized in the same manner as the direct-current generators. No special equalizing connections are made, however, to those coils which are connected to the collector rings as the collector rings serve the same purpose.

WINDING THE ARMATURE

In a wave or two-circuit winding, all the coils between two diametrically opposite points on the winding are in series with one

another, while in a lap winding, only the coils between adjacent pole centers are in series. Thus, other conditions being equal, the voltage in a wave winding will equal the voltage in a lap winding multiplied by the number of pairs of poles. And the voltage between commutator segments will vary in the same ratio. To secure the same voltage for the machine, it is evident that the relative number of coils in the two types must vary inversely with the number of poles, and the size of the coils in the wave winding must increase in proportion.

The wave winding has the decided advantage that no cross-connections are required. It has, therefore, a very extensive application on machines in which the size of coil does not become excessive, nor the voltage between segments too great to allow of good commutation. Ordinarily, however, this consideration limits the use of this type of winding to four or six pole machines, and, where the number of poles is greater, the lap or multi-circuit type of winding is universally used on direct - current machines. With this winding, not only is the voltage between segments kept down to reasonable limits, but great conductivity through the armature can be readily secured without using coils of excessive cross-section.

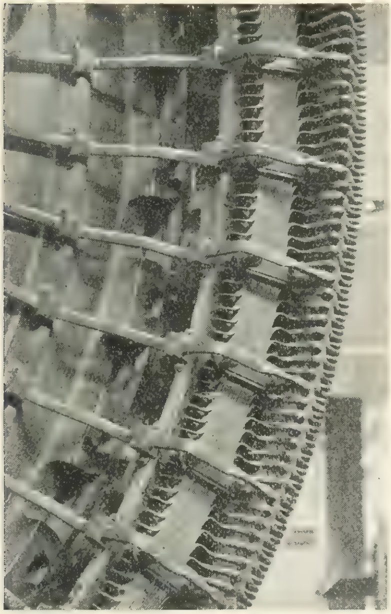


FIG. 97—DETAIL OF CROSS-CONNECTIONS AT REAR OF ARMATURE OF 3000 KW ROTARY CONVERTER

Both types of windings are ordinarily wound with one piece coils. Two-piece coils have, however, some advantages and are used to a certain extent; less care and skill is ordinarily required in the winding operation, and there is no need of removing any of the coils after they have been once placed in a slot, as must be done with the throw coils of the one-piece type. Also the windings can be more easily repaired if the top half of the coil only is damaged. On the other hand a soldered joint is necessary

at the rear of the armature, which requires considerable time and skill, and on the larger machines, where a winding jig is impracticable, it is difficult to secure a symmetrical shaping of the rear end of the armature.

Insulating the Core—As a preliminary to the winding operations the core is thoroughly cleaned with an air blast, thus removing any iron filings or other foreign matter from the slots. The commutator necks are then carefully examined to see that all are straight and that the openings at the top are wide enough to admit the coil leads easily. The commutator is tested for breakdown to ground, and for short-circuit between segments, with the standard test voltage for the machine. All parts of the spider which come in contact with the coils, such as coil supports, etc., are carefully in-

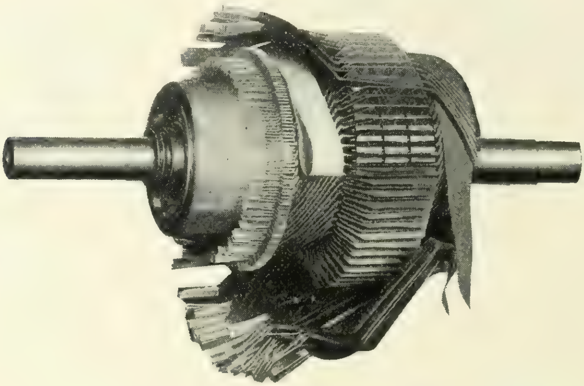


FIG. 98—WAVE WOUND ARMATURE, PARTLY COMPLETED

sulated with either tape, fullerboard channels, or two or three thickness of fullerboard strips. When tape is used it is wrapped in overlapping layers over the entire support. At the point where the spurs which hold the coil support in position prevent winding on the tape, the iron is covered with cloth, which is held in place by the tape on each side. Each layer of the tape is shellaced as it is wound. When fullerboard strips are used, the first layer is frequently screwed to the iron to prevent lateral motion. Other layers are shellaced over this, and the whole is usually bound with twine. Special care is taken to stagger all joints.

Inserting the Coils—The assembly of the different types of coils is essentially similar. Two slots are marked with chalk to receive the first coil, and the commutator necks into which its leads will be connected are counted off and marked. Fish paper cells are inserted into the slots, and the coils are driven into position one

after another, with a mallet and fiber drift. If a two-piece coil is used, the lower half-coils are inserted first, all the way around the armature, and then the upper half-coils. If one-piece coils are used, the coils are inserted in regular succession, the bottom half of the coil being driven into the bottom of its slot first. The other half is driven into close contact with the coil which is already in the bottom of the slot. If there is no coil in the bottom of the slot, as happens with the throw coils, this top half is inserted only temporarily until the winding has been carried entirely around the armature, when the throw coils must be removed, so that coils can be placed in the bottom of the slots.

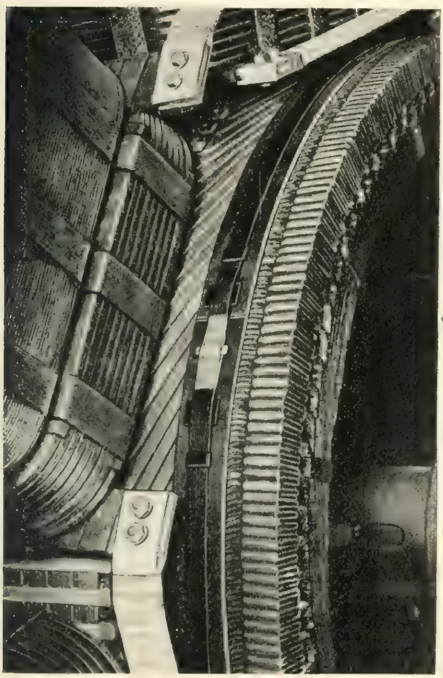


FIG. 99—DETAIL VIEW, REAR END OF ARMATURE
Two-piece coils; sectional banding.

When a one-piece coil is used in a wave winding, the throw coils span so large a part of the armature that it is not usually advisable to insert the upper part of the coils into the slots and then remove them again. The coils are, therefore, allowed to hang free, as shown in Fig. 98, until all coils have one side in place. The upper parts can then be driven into their permanent position, in regular order.

The upper and lower coil ends are separated by bands of oiled duck or drilling. With one-piece coils this is threaded in place as the coils are inserted. With two piece coils it is simply wound over the lower set of coils before the others are placed in the slots. With certain types of coils, where the coil ends do not fit closely together, "U" or "L" shaped pieces of treated fuller-board are placed over both the upper and lower coil ends, thus separating the adjacent coil ends, as well as the upper

and lower layers. In some cases, these strips are placed over the ends by the coil winder, and covered with the last layer of tape. This makes the winding very compact at the ends.

The coils must be a close fit in the slots, in order to prevent any possibility of chafing. If necessary, strips of fullerboard or treated wood are inserted at the sides or bottom of the slot, to make the coils a tight fit. As each top coil is put in place it is driven into the slot, the protecting cells are cut off, and folded over it, and fiber wedges are driven into the wedge grooves. The slots on a large sized machine are too long to allow one wedge to be used, so one or more are driven in from each side of the slot, furnishing complete protection for the face of the coil. The armature is then tested for grounds, before the connections are soldered.

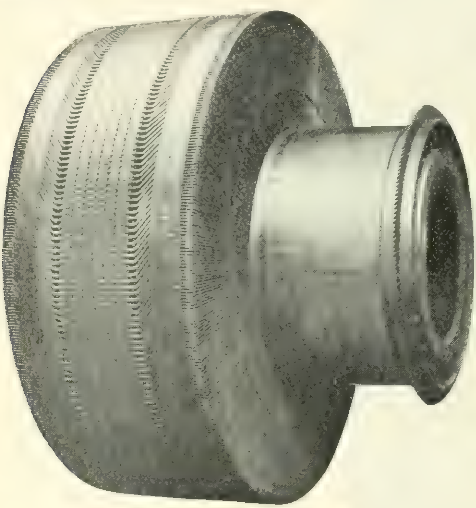


FIG. 100—ARMATURE OF 3000 KW GENERATOR, 600 VOLTS, 300 R. P. M

After the winding is completed, the armature is banded temporarily at both ends. Wooden wedges are then driven in between the commutator necks, being first driven in loosely all around the armature to insure even spacing and then driven in tightly, forcing the necks and coil ends into tight contact and holding them rigidly in place. With two piece coils, connecting clips are placed over the leads at the rear end, and wedges are driven in between these in the same manner. The connections to the necks, and the rear end connections, if any, are then soldered. This soldering is always done on the side of the machine instead of the top, as a better joint can be made in this manner, and there is less liability of the melted solder running along the necks and short-circuiting the commutator segments.

Before removing the wedges the armature is mounted in a lathe, or if no suitable lathe is available, in its bearings with the field frame removed, and the soldered connections are turned down. If the armature is mounted in its bearings, a suitable tool

holder must be fastened to the frame, or some rigid support. The commutator is also turned down and given its final polishing at this time. The wedges are then knocked out from between the leads, and the sharp corners are rounded off with a file. The bare copper is not covered with insulation, but insulating material is sometimes inserted between the adjacent leads to prevent accidental contact. At the rear end, this usually takes the form of asbestos tape which is interwoven between the leads as shown in Fig. 99, or of canvas hoods, sewed in place. At the front end, the necks may be separated at the tops by strips of heavy fish paper, bent over the tops of the leads so as to be held in place by the band wires. Where the necks are quite long, additional separators are inserted about half way up from the commutator. These may be in the form of fiber buttons or may merely consist of heavy twine, interwoven between the necks, as shown in Fig. 100.

FIG. 101—TOOL USED FOR TIGHTENING SECTIONAL BANDING

BANDING

Bands of steel wire are ordinarily placed over both ends of the armature, and frequently another over the connections to the commutator necks. No bands are used over the surface of the core, as the wedges are sufficient to retain the body of the coils in place. The coils are protected from the mechanical pressure of the banding by layers of surgical tape separated by strips of cement paper, over which the bands are wound. The wire is wound on under heavy tension, secured by clamping it between blocks of wood. These blocks are held from moving by heavy straps of wire, fastened to some rigid object—usually the machine frame. If desired, a spring balance may be inserted, which will give the exact tension which is being applied. This should run between 300 and 400 lbs. The bands are firmly soldered in place. When it is desired to secure extra mechanical strength, the wire is sometimes wound

on two or three layers deep, each layer being soldered separately.

The proper banding of a large armature by this method is often a serious problem, especially on a repair job. A sectional band is therefore used which retains all the good qualities of a continuous wire band, yet can be applied or removed repeatedly without difficulty. The appearance of a band of this type in service is shown in Fig. 99, while Fig. 101 shows the clamp employed to mount them in position. The sections are keyed together into an open loop and are placed in position on the armature. To make the final connection, the clamp is placed over the end of the band, the two jaws gripping the projecting ends of the fixed piece let into the ends of each section for that purpose. The handle, whose

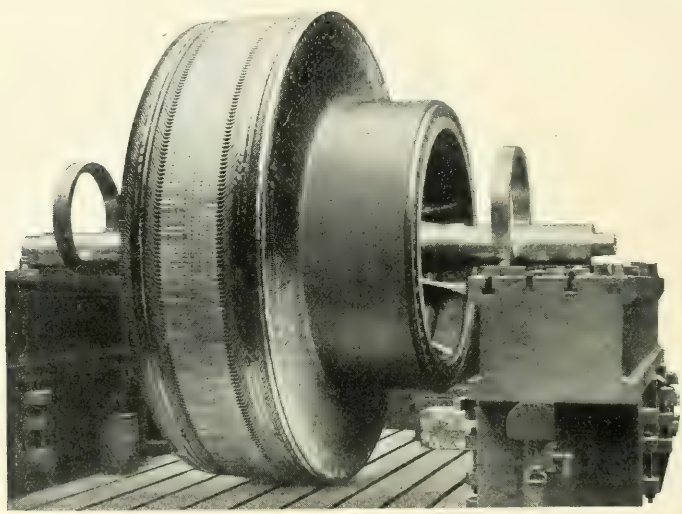


FIG. 102—3 000 KW ARMATURE ON BALANCING WAYS

lower end is formed into a cam, is then brought down to a position in line with the beam, thus forcing the jaw forward and interweaving the loops on the section ends. The pin *A* is inserted in the holes through the movable jaw and beam, and the handle is removed and advanced to the next hole in the beam. This operation is repeated until the ends of the bands are interlaced sufficiently to permit the steel key *B* to be inserted. The tool is then removed and the banding painted with shellac.

BALANCING

After the banding is completed the armature is placed in the balancing ways. These consist of heavy steel beams, with polished steel plates mounted on their upper edges. The surface of the

polished plates is accurately leveled. The shaft rests on the inner surface of a polished steel ring, which in turn rests on the polished plates as shown in Fig. 102. In this way, an almost frictionless bearing surface is obtained, and the armature tends to roll until the heaviest part is at the bottom. Melted lead is poured into recesses in the spider, or cast iron weights are bolted to the spider arms to correct any unbalanced condition, until the armature will lie with any part uppermost. The armature is then thoroughly cleaned with an air blast and sprayed inside and out with black finishing varnish. Special care is taken to reach all exposed parts of the core, to prevent rusting.

ROTARY CONVERTERS

There is no essential difference in the winding operations as described between rotary converters, and other direct-current machines. At the rear of the armature, however, taps are brought out from the coils at regular intervals. On a three-phase machine, this will be two-thirds of the pole pitch; on a two-phase machine, one-half the pole pitch, and on a six-phase machine one-third the pole pitch. These taps are connected to the collector rings, as shown in Fig. 97. A two-phase or a six-phase rotary converter cannot be wound with a wave winding on account of the necessity of having an equal number of coils between taps on the armature.

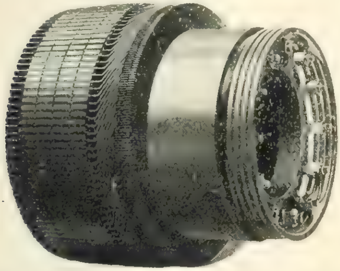


FIG. 103—ARMATURE OF THREE-WIRE GENERATOR

THREE-WIRE GENERATORS

Practically any standard generator can be adapted for use as a three-wire machine by the addition of suitable collector rings and balancing coils. These coils are entirely self-contained and are installed apart from the generator. The collector slip rings are usually much smaller than those of a rotary converter, as each one carries only a fraction of the unbalanced current. The current which they carry is largely unidirectional, only enough alternating current flowing to excite the core of the balancing coils. They are accordingly made of iron to avoid the blackening from electrolysis which takes place when the direct current flows from copper to carbon. They may be placed at either end of the armature, but are usually placed at the end of the commutator, as shown in Fig. 103, for greater convenience.

CIRCUIT BREAKER RELAY SYSTEMS FOR POWER TRANSMISSION

R. P. JACKSON

[This is the seventh of the series of articles on the general subject of continuity of service in transmission systems dealing particularly with static stresses and line troubles, and the proper protection of transmission systems from such troubles.]

THE development of the automatic circuit breaker at first involved a device which would trip a latch and open the circuit under a simple overload. The successful performance of this work caused the development of various types of circuit breakers to perform more intricate functions in which the assistance of specialized relays was required. For this purpose relays having characteristics of reverse current, reverse power, no voltage, definite time element, inverse time element, etc., were devised and have found useful application. The application of these various relays, however, involves more than the characteristics of the relays themselves and requires their being fitted into the system of power transmission in such ways as will give the desired results.

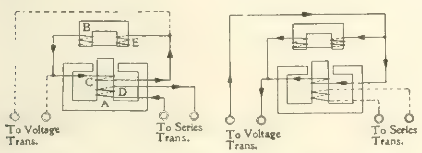
As used on transmission lines, circuit breakers and their relays are not so much required for over-load purposes as for the elimination of defective lines. The strictly over-load requirements can ordinarily be met by circuit breakers on the low-tension side of sub-station transformers. On the other hand, the certain localizing of a ground or short-circuit on a transmission system without serious disturbance to the delivery of power to otherwise unaffected apparatus is often a different problem.

An endeavor is made in this article to describe some of the methods by which this may be accomplished in various degrees of completeness. The three abnormal circuit conditions which may arise and for which relays may be arranged to serve in cutting out the damaged portion of the circuit are, reversal of current, a ground, and loss of current between stations or, in other words, cases in which an appreciable portion of the current leaving one station does not reach the receiving station.

THE REVERSE CURRENT RELAY SYSTEM

While a direct-current relay may be given a selective action between two directions of current by means of a permanent

magnet, this is only possible in an alternating-current relay by the use of a winding having a fixed phase relation to the rest of the circuit. In practice a voltage coil on the relay supplies the right characteristics. The phase relation of current to voltage, which in case of entire reversal, indicates a reversal of the flow of power, changes the direction of torque of the relay and thus causes it to make a contact. The first difficulty encountered in the development of a successful alternating-current relay was that if a short-circuit occurred near the relay, there would not be enough voltage at the time of the short-circuit to afford any torque whatever, Figs. 1 and 2, show how this defect has been overcome by the addition of a separate winding on the relay in proximity to the current coil but connected in parallel with the voltage coil.* Then in case of a short-circuit leaving no working voltage, the transformer action between coils *C* and *D* of Fig. 1 still affords the desired torque. The active circuit conditions when no voltage is present are then indicated in Fig. 1. The conditions when no current is present are indicated in Fig. 2.



FIGS. 1 AND 2—DIAGRAMS OF REVERSE CURRENT RELAY
Showing active windings with no voltage and no current, respectively.

For the several division settings of the relay, a tripping by reversal of power flow when voltage and current are present occurs at a much lower value than for a normal power flow toward the load. In case of a short-circuit in which there is no voltage at the point where the relay is connected, the operation of the instrument is that of a simple over-load relay operating from current in either direction. The characteristics under these two conditions are illustrated in the curves of Figs. 3 and 4.

In case of a short-circuit on one of two lines entering a receiving station and in close proximity to this station the voltage may be very low on both relays and almost no selective action remains between the two sets of relays. Recourse may be had

*See article on "A New System of Sub-Station Relays for Incoming Transmission Lines," by Mr. Paul MacGahan, in the JOURNAL for Nov., 1908, p. 638. The type of relay described therein represents the highest development of the reverse current relay. Its working parts may be seen to resemble an ordinary wattmeter.

to an additional selective device, the function of which would be to instantly open the trip circuit of each relay when the power is in the positive direction, thus preventing the main relay from completing the trip circuit when it makes contact. This selective device is an ordinary contact-making wattmeter-type relay with the contacts so adjusted that at zero power its contacts are closed; the required controlling force is so slight, however, that the contacts will be opened when the watts in the relay coils are five or more in the positive direction, the full-load rating of the coils being five amperes at 100 volts, or 500 watts. Thus when a short-circuit occurs just outside the receiving station, the voltage being barely sufficient to cause a destructive flow of current, a voltage of one percent of full load would be sufficient

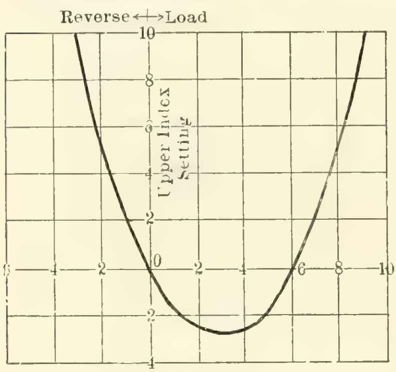


FIG. 3—CURVE SHOWING OPERATION OF RELAY WITH CURRENT AND VOLTAGE APPLIED

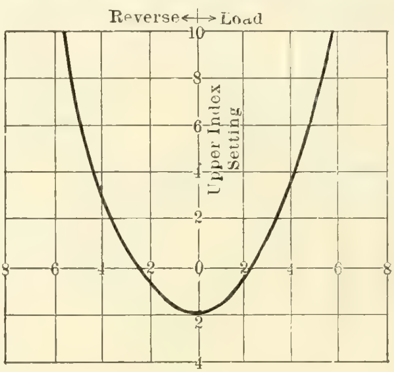


FIG. 4—CURVE SHOWING OPERATION OF RELAY WITH CURRENT ONLY

to operate this selective device. A complete diagram of connections for the relay circuits, including the selective watt relays is shown in Fig. 5. It should be understood, of course, that the strictly overload operation of the main relay is nullified by the addition of the selective watt relay, and must be obtained, if required, by the use of additional over-load relays.

For the protection of lines leading from one power station to other stations supplying loads such as lights, induction motors, etc., the relay system described above has proved very effective and satisfactory. If, however, power is fed into a system at more than one point, or if there is synchronous apparatus of large capacity at some of the sub-stations, an actual reversal of power on both lines from a station, may occur, in which case

the relays would of course cut out both lines. In other words this relay system can be made practically perfect for operation on two or more parallel lines in cutting off an actual reversal of current at the receiving station. It can not, however, take account of what may be occuring between stations or at another station.

RELAYS THAT OPERATE IN CASE OF GROUNDING OF THE LINE

On a transmission line, especially one carried on steel towers, an insulator often becomes defective without immediately producing a short-circuit. Protective devices are also being used to prevent insulators from being shattered by the power arc following a "spill-over" due to lightning. Either of these conditions may produce a ground on one line wire, and it becomes necessary to cut out for a time the line on which the ground exists without

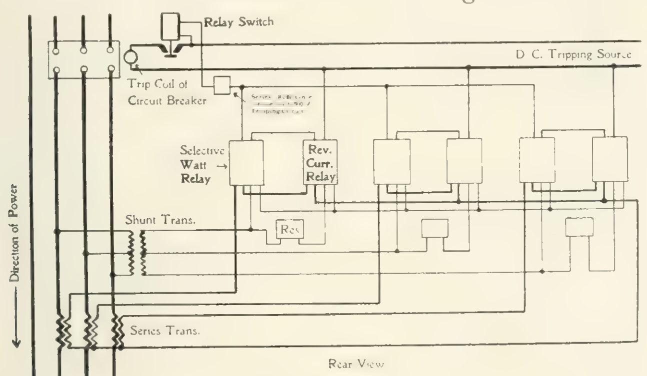


FIG. 5—CONNECTION DIAGRAM FOR COMBINATION OF THREE SINGLE-PHASE REVERSE-CURRENT RELAYS AND THREE SELECTIVE WATT RELAYS ON A THREE-PHASE, FOUR-WIRE CIRCUIT

disturbing the adjacent lines. Fig. 6 shows the connections of a special relay system devised by Mr. L. C. Nicholson of the Niagara, Lockport & Ontario Power Company. Several forms have been worked out which operate either by means of the current flowing through the relay to the ground on the affected line and back through a grounded neutral of the system, or from the unsymetrical charging currents of the three wires of a three-phase line with one wire grounded. The principle involved in all is the selective operation of a relay from the single-phase excess current resulting from a grounded wire. It can be worked out for a system having no neutrals grounded, but has so far found practical applications in connection with a grounded system substantially as shown in Fig. 6. This system does not operate properly in case of a short-circuit or where two separate wires

are grounded, consequently its application is somewhat special. Within its limits, however, it is reported to operate very satisfactorily.

RELAYS OPERATING FROM LOST POWER

It seems to be practically impossible to accomplish all that is desired on a transmission line with any relay system that does not coördinate the operation of the relays of the two stations at the ends of a section of transmission line. The reversal of power in a line may not be a proper reason at times for disconnecting that line; for that reason no reverse current or reverse power relays can, under all circumstances, be satisfactory. Faults may develop in the form of either grounds or short-circuits or both and of varying degrees and locations. Consequently the

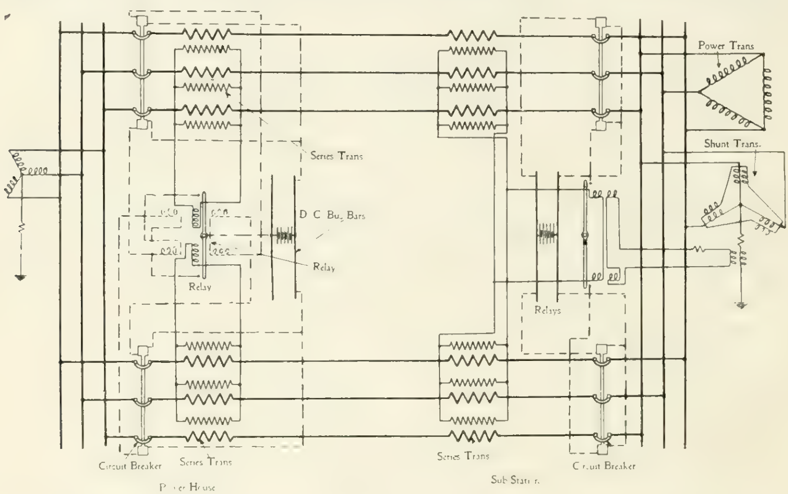


FIG. 6—DIAGRAM OF RELAY SYSTEM OPERATIVE ON GROUND ONLY

essential thing as far as the integrity of the line is concerned, is to know that all the power, outside of line losses, that leaves one station reaches the next station. No way has been found to cut out a defective line under all proper conditions and not under improper ones, that does not involve the carrying of relay connections between stations.

An arrangement is shown in Fig. 7, which has been worked out to accomplish the desired result by means of three series transformers at each station connected to three relay lines as shown in Fig. 8. The series transformers at the two ends of the section of transmission line are so connected as to short-circuit each other's secondaries; accordingly, there is no drop except that in the relay wires between stations. The only voltage at the

terminals of these series transformers is that due to this relay line drop. If the line power current becomes excessive or several times full-load current, the current in the relay lines, which of course must be proportional to the line current, will cause sufficient resistance drop to operate the relays and trip the circuit breakers at both ends of the section of line. Again, if there is any fault in the line between stations which prevents some of the current which leaves one station from reaching the next, the excess secondary current from the station carrying the greater current develops a potential in passing through the secondary of the corresponding series transformer at the other station and thereby operates the relays and circuit breakers as before. A re-

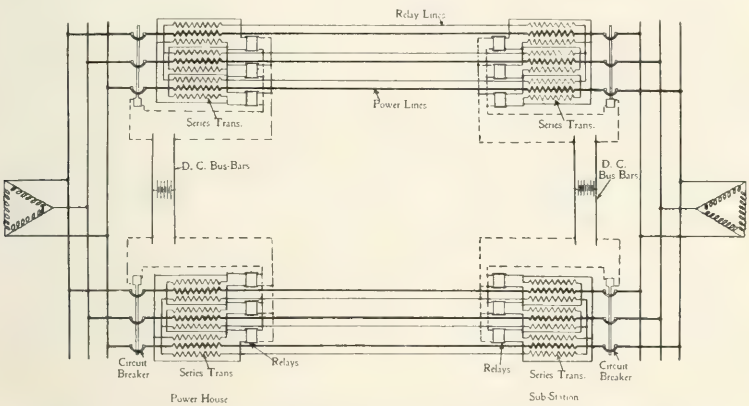


FIG. 7—DIAGRAM OF RELAY SYSTEM TO OPERATE FROM LOST POWER

versal of current in the line does not and should not cause the circuit breakers to open. Short-circuiting the relay lines will leave the system unprotected, but breaking of one or more of the lines will trip the circuit breakers and cut out the line.

This type of relay connection may be used in either a loop system of distribution or on one where the power is delivered into a network of branching lines from a power house at one point. It will also be found satisfactory in case several power stations feed into a network at different points. The only limitation is that all branch lines must be taken off from station busbars and not connected to a line between stations.

This relay system is being worked out on lines of the Hydro-Electric Power Commission of Ontario. The handicap under which it labors is that three relay wires of a certain limited total resistance must be carried between stations. The expense of such wires may or may not be serious, depending on the distance and

the amount of power carried. A modification of this system is illustrated in Fig. 9. Ordinary reverse current relays are used at both ends of the section of line. The operation of any one of them causes the operation of a relay switch. A storage battery is provided at each station and the connections of this battery circuit through the relay switch contacts and the circuit breaker trip coils is such that the two batteries are of opposing polarity and resulting voltage is their difference. Under this normal condition the circuit breakers will not be tripped, and so long as both stations are carrying power in the same direction this condition remains, since a reversal of the direction of power causes both relay switches to reverse. If, however, there is an actual reversal of power or current at one station and not at the other the position of the relay switches will be such that both batteries are in series and the sum of their voltages is applied to the circuit-breaker trip coils, thereby opening the breakers.

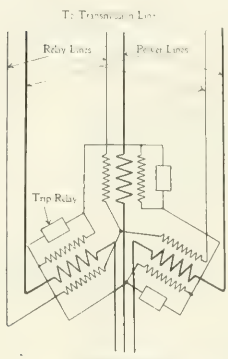


FIG. 8—SERIES TRANSFORMER CONNECTIONS FOR LOST POWER RELAY SYSTEM

But one relay wire is needed with this system, as a ground return can be used. The grounding of this one wire will trip the circuit breakers, while an open circuit will remove the protection. While demanding but one wire between stations this system requires an actual reversal of current to operate the primary relays. The arrangement previously described, on the contrary, would take account of a fault which indicated lost power, even though the aggregate current might be in the same direction in both stations, though of less quantity in one than in the other. This difference might be of minor consequence, however, if the transmission line were carried on steel towers, as any fault would probably develop into a short-circuit.

OPERATION WITHOUT RELAYS

It sometimes develops that simpler and more generally reliable operation can be obtained without any over-load or reverse current protection, while in some cases a simple over-load relay system with definite time element is the most satisfactory. When the power station and line are of moderate capacity it has been found practical, in case of trouble, to simply lower the voltage on the

generating system until a short-circuit has cleared itself and then raise the voltage and resume operation. This is of course a somewhat crude method of operating, as is also the burning off of a ground or short-circuit, and is only applicable to systems of limited capacity.

Another method which has given fair results is to carry two lines to each sub-station, but let each station draw power from only one at a time, the lines to be parallel only at the power station.

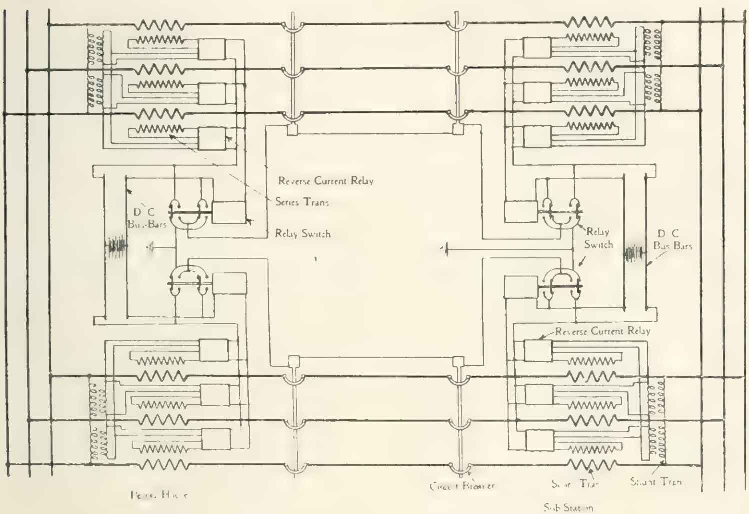


FIG. 9—CONNECTIONS OF A "LOST POWER" RELAY SYSTEM REQUIRING BUT ONE RELAY WIRE

tion. If, with this system of operation, over-load relays with definite time element are provided at the power-station and intermediate switching stations and set for progressively longer periods from the distant ends towards the power station, only the defective portion of the line will be cut off and power can at once be obtained at any station by closing the switches to the other live line. In the absence of a complete relay system with relay wires between stations this arrangement probably gives the minimum disturbance to the whole system and the shortest interruption to the affected sub-stations that can be obtained on lines affected by lightning, etc.

With the development of large and complicated networks of transmission lines carrying heavy and important loads, it is essential that the question of relay and circuit breaker protection be studied carefully, as at present the line is the least reliable element of any extensive power transmission system.

THE JOURNAL QUESTION BOX

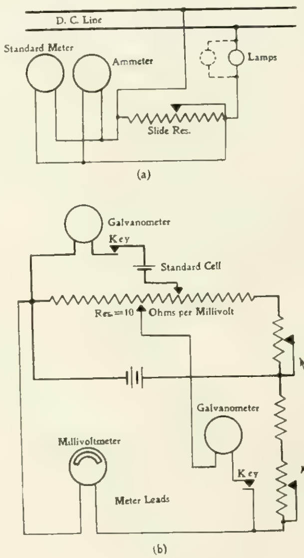
Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

495—Method of Calibrating Shunted Direct-Current Ammeter—Please give method of calibrating a 600 ampere ammeter (Weston) using a shunt. Can this be done without breaking the circuit? Can it be done by means of a simple potentiometer? F. G. F.

There is no difficulty in calibrating shunted direct-current ammeters by means of a potentiometer if the resistance of the shunt is known. Since $I = \frac{E}{R}$, if E is measured and R is known, it is a simple matter to calculate I. When it is necessary to introduce a standard shunt or a standard ammeter of any form into the circuit without interrupting the current, the standard should be connected in multiple with some switch which is in the circuit, while it is closed. After connecting, open the switch and let the current pass through the standard instead. For information regarding the construction and use of a potentiometer suitable for such measurements see article by Mr. H. B. Taylor, in the series on "The Standardizing Laboratory," in the JOURNAL for Dec., 1906, p. 686. H. B. T.

496—Method of Calibrating Shunted Direct-Current Ammeter—I am often called upon to calibrate ammeters of as large capacity as 6000 amperes where the available load is no higher than 800 amperes. It is always desirable to make calibrations at zero and full scale reading. With only simple portable apparatus at hand it appears to be more of a problem than simply using Ohm's law. I have a wheatstone bridge and a millivoltmeter; the latter can be used with switchboard shunts and gives a full scale reading of 60 millivolts. I can get the millivolt drop of the shunts used in connection with the ammeters, which is very near 60 millivolts. From this I can find the amperes for each division of the millivoltmeter, as it is connected in parallel with the switchboard shunt and ammeter; that is all right on the loads which are used, but when an ammeter is only loaded sometimes to five or six percent of its full capacity what am I going to do to get a full scale reading? I must use the voltage at the busses, either 110 or 220 direct-current, and the instruments at my disposal. Of course I can make a single slide resistance if that is needed. I will greatly appreciate further information. F. G. F.



FIGS. 496 (a) and (b)

The full-load drop of shunt being known, and millivolts for any other load therefore easily calcu-

lated, disconnect ammeter from its shunt and compare with the standard 60 millivoltmeter, being careful to include the leads of both meters in circuit when they are connected in multiple for comparison. The current for operating the meters may often be most conveniently obtained from a dry cell but if it *must* be taken from a direct-current line, connect a variable resistance in series with one or two lamps and shunt the millivoltmeters across it as shown in Fig. 496 (a). In addition to the wheatstone bridge you need only a galvanometer, a standard cell and a few dry cells to arrange for the equivalent of potentiometer method for checking your 60 millivolt standard millivoltmeter. This method is shown in diagram Fig. 496 (b). Two galvanometers and keys are shown to simplify the diagram. By using a double-pole, double-throw switch, one galvanometer and key will answer. The method of procedure is as follows: First, connect the standard cell through a key across a resistance in the bridge rheostat which is a convenient number of ohms per millivolt e.m.f. of the cell; for example, if the cell voltage is 1.0198 volt connect it across 10198 ohms. Then adjust the current in the bridge coils to give a drop which balances the cell voltage, and the drop across any part of this resistance will be one millivolt for each ten ohms. Adjust the millivoltmeter current to balance the drop across any desired part of the resistance and take the reading. H. B. T.

497—**Static Shocks from Motor Equipments**—A number of induction motors on our service have given considerable trouble due to slight shocks felt at the frame of the motor. This is more severe in motors installed where there is no wooden floor. A test with a magneto shows the motors to be free from grounds. This current, which we believe to be a static discharge, follows conductors of high resistance, in one case making a work-bench "alive." We have tried grounding the motor castings with good results in some cases. Our transformers are not all grounded, and we have no lightning arresters. The system is 2300 volt, three-phase, 60 cycle, with power and light transformers taking current from the same mains. What is the explanation of this trouble, and what is the remedy? C. R. D.

Since the voltage on the high-tension side of the transformers is but 2300 volts, it is scarcely possible that the shocks referred to are caused by any electrostatic effect due to the transformers. In all probability the cause of the trouble can be traced to the generation of static electricity by the belts. Very painful shocks can sometimes be received from apparatus, due entirely to this cause. In addition to grounding the frame of the motor, try grounding the belt to the motor frame by means of a suitable "brush" collector composed of a number of projecting wire points arranged near the surface of the belt and connected to ground. The brush need not come in contact with the belt, as it will collect the static charge through an intervening air-gap. M. W. B.

498—**Over-Heating of Bearing on Small Induction Motor**—Difficulty is being experienced with a number of induction motors, all less than 15 hp capacity, because bearings at the pulley end persist in running hot, although upon examination the journals appear to be in first class condition, the rings run free and the oil is clear. Would you advise the use of flake graphite in conjunction with the regular ring-oiling system to obtain better lubrication? H. A. F.

It would appear that the belts are too tight or that too small pulleys are used, either of which conditions would result in hot bearings. If the bearing is properly designed, if good babbitt is used, and the bearing runs free, there is ordinarily nothing to be gained by the addition of auxiliary lubricating substance to a good quality of lubricating oil. Loosening the belts and the use of a small amount of

belt dressing may be found to improve operation. See No. 457.

A. M. D.

499—Operation of Shunt-Wound Motors—A 110 volt, ten horsepower, variable speed, shunt-wound motor is connected through gearing to drive a triple geared lathe having a 32 inch swing. It has a range of speed control of 400 to 1 600 r.p.m. It was connected correctly to the starting box and as an experiment an improvised water rheostat was inserted in the field circuit. The motor, however, scarcely attained a speed of 400 revolutions, while 1 600 r.p.m. was desired. Reversing the connections gave no remedy; accordingly, a second, and finally a third water rheostat was added in series with the first, and the carbon brushes were sandpapered very slightly. When the current was now thrown on, the motor speeded up and attained full speed. Please give the probable explanation of the action of the motor. Was it the inserting of resistance in the field circuit which caused the motor to run faster or is it probable that the desired operation was obtained as a result of sandpapering the brushes? Why was this necessary when the voltage was that for which the motor was designed? What effect does increasing the load from no-load to maximum have on the speed of a shunt-wound motor? O. K.

The insertion of resistance in the shunt field was responsible for the material increase in speed. It seems probable that the first rheostat contained impurities sufficient to make its resistance so low that when put in series with the shunt field it had practically no effect on the motor speed because the change of shunt field current was only very slight. The second and third water rheostat probably contained much purer water, their resistance therefore being very much higher than the first, so that when put in series with the shunt field they served to reduce the shunt current and therefore to cause the speed of the motor to increase. Varying the load on a shunt motor from no-load to full-load has the effect of reducing the speed somewhat. The amount of speed reduction depends primarily on, and is approximately proportional to, the internal *ir* drop of the motor. Sandpapering the brushes would not have the effect of causing the motor to come up to speed more readily in the second case than in the first. Grinding the brushes so that, in one case, the toe or, in the second case, the heel of each rests on the commutator will have the effect of changing the speed through a range of possibly five to ten percent, depending on the thickness.

F. A. R.

500—Power-Factor of Induction Motors and Transmission Line—Assume that alternating-current is supplied from a generating station, via a transmission line, to five motor circuits, tapped in on the transmission line at the consecutive points, *A*, *B*, *C*, *D* and *E*, Fig. 500 (a), these respective side circuits supplying power to induction motors in a cor-

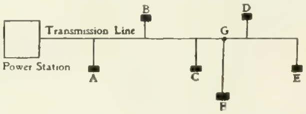


FIG. 500 (a)

responding number of manufacturing establishments, the side circuit *A* being nearest the power station. Assume, also, that each of these five establishments takes a constant load and that the respective loads are equal, but that on account of certain local conditions of motor load, the power-factors at *A*, *B*, *C*, *D* and *E* are respectively 88, 86, 84, 82 and 80 percent. *a*—Will a power-factor meter inserted in the transmission circuit between *A* and the power station indicate the average of the five power-factors given (viz., 84 percent)? *b*—Will a power-factor meter placed between *A* and *B* be influenced by the power-factor at *A*? Assume now that between *C* and *D* a tap

is taken off the main line at the point *G* to another plant situated at *F* (say, one mile from the main transmission line) where only one induction motor is used, its power-factor being 90 percent. *c*—Will the power-factor of the motor at *F* be influenced in any way by the power-factor in the main line between *C* and *D*? *d*—Will the power-factor between *G* and *F* be governed solely by the power-factor of the motor at *F*, and will the power-factor at any point from *G* to *F* be 90 percent, i. e., the power-factor of the motor at *F*? Assume again that for some reason the customer at *F* desires to install a synchronous motor to develop a given brake horse-power and in addition have sufficient extra capacity to raise the power-factor of his own circuit (i. e., from *G* to *F*) to 95 percent. *e*—Will the required extra capacity of this synchronous motor be governed solely by the requirement of raising the power-factor of his own system from 90 to 95 percent, or will the power-factor of the main line between *C* and *E* also have to be considered? *f*—If the extra capacity of the synchronous motor is governed solely by the motor at *F* will the power-factor of the main line between *C* and *E* be raised due to raising the power-factor between *G* and *F*? *g*—Will the actual power-factor of the motor itself be raised to 95 percent or will the motor still operate at 90 percent, but the circuit external to the actual motor be raised to 95 per cent? H. L. S.

The resultant power-factor of the circuits will be slightly lower than the average if the kw loads are assumed to be equal at each instant, while with equal k.v.a. it will be somewhat higher. Where the difference in the power-factor of the different circuits is small, as in this case, the variations of the resultant from the average is but a fraction of one percent. A power-factor meter indicates the resultant power-factor of all circuits on the side furthest from the source of power; consequently it will show a lower reading when connected between *A* and *B* than if connected between *A* and the generators. The power-factor anywhere between a motor and the point of intersection of its circuit with another will be that of the motor. To figure on correcting the power-factor of a branch circuit consider the local load conditions and disregard the remainder of the system. The power-factor of that part of the system between the generators and the point *G* will be improved to some extent by raising the power-factor of the circuit *G F*, but from *G* to *E* it will be unaffected. The power-factor of induction motors is independent of the power-factor of the system. The power-factor of a corrected system is the resultant of the lagging power-factor of the induction apparatus and the leading power-factor of the synchronous condenser. For further information regarding power-factor correction see editorial by Mr. P. M. Lincoln in the JOURNAL for Jan., 1907, p. 2, and "Notes on the Construction, Performance and Operation of Alternators," Oct., Nov., Dec., 1906, pp. 545, 631, 668; also No. 470. S. N. C.

501—Phase Wound Rotor Rewound as Squirrel Cages—We have a 35 hp and a 50 hp, three-phase induction motor, each of the wound secondary type having the secondary resistance mounted on the inside of the rotor. The resistance is cut out by sliding contacts. The contacts and the winding have been giving considerable trouble. What would be the result if the resistance were removed and the rotor windings short-circuited by means of a copper ring, using an auto-starter to start the motor? What would be the result if the rotors weres rewound as a squirrel cage type, using copper bars of the same cross-section as the copper now in the slots and suitable short-circuiting rings? A. B.

Under severe starting conditions the operation of the motors in question would not be satisfac-

tory if the starting resistance were removed and the winding short-circuited. This is due to the fact that the resistance of a phase-wound secondary is small and the "locked" or starting torque is correspondingly small, while the locked amperes or starting current is correspondingly increased. The action of an auto-starter is not to increase the starting torque but to limit the starting current at the expense of the torque which is developed by the motor in starting. It is very probable that even on full voltage the motor would not develop sufficient torque at starting to bring its load up to speed. If starting conditions are not severe, e. g., starting light machinery without load or without heavy friction, the short-circuited winding will operate successfully at a slight expense of starting current. It would be possible to substitute a cage winding with properly proportioned resistance rings, but the amount of copper in the slots and the dimensions of the rings should be determined by the constants of the machine with reference to the operation desired. The best method would be to obtain a complete new revolving part supplied with a squirrel cage winding. In all probability this could be obtained from the original manufacturers. M. W. B.

502—Power Consumption of Desk Type Fan—Please give method of determining power required to drive a fan of the desk type of given dimensions, running free in air at a given r.p.m. E. C. E.

The power required to drive a fan, independent of that lost through the manner of drive, is a very uncertain quantity to calculate. It can be expressed by a formula of the general form: $W = KS^3D^5\tan^2\phi$, where W=watts to rotate the blades; S = speed of rotation in r.p.m.; D = diameter of fan in inches; ϕ = angle which the plane of the blade makes with a plane perpendicular to the shaft; K = a constant. This constant is made up of two parts, one fixed but depending on the system of units used, and another varying with the type of blade and the number of blades. For a 12-inch, four-blade desk fan running at 1 660 r.p.m., with a blade shape of high efficiency and an angle ϕ of 16 degrees, $K = 24\times10^{-12}$. This gives W = 15 watts at 1 660 r.p.m. The limits over which this formula can be applied are not known, but it will probably be found to be correct for values of S, D, and ϕ, varying from 50 to 200 percent of those given in the example. K will vary for three and six blade fans nearly in proportion to the number of blades. However, it will change greatly for improperly shaped blades, reaching a value of even 40×10^{-12} with some blades on the market. While increasing the number of blades will increase the power consumed, it destroys the efficiency of the fan to such an extent that very little is gained by adding blades beyond a certain number, say, four blades for a high-speed fan. O. S. J.

503—Testing and Adjustment of Polyphase Integrating Wattmeter—When testing a Westinghouse Type *A* polyphase wattmeter with each element of the meter connected separately on a single-phase 100 volt circuit I find trouble in balancing the two circuits. Is it best to shunt the current transformer terminals at the meter with a wire of suitable resistance? Also, for balancing these meters on varying power-factor, please give data for making up an impedance coil with suitable taps for one, two, three, four and five amperes. L. J. T.

It is understood from the question that the torque on the two elements of the meter is not the same. Balance can be obtained in one of three ways, viz., *1*—shifting the discs on the shaft, i. e., making them closer to or farther from the shunt pole; *2*—shifting the electro-magnets, each element separately, backward or forward on the frame; *3*—changing the air-gap in one of the impedance coils. The last method is rather difficult after the meter has become old, but either of the first two methods can be used satisfactorily. To check the meters on low power-factor, the best arrangement is to

use two-phase or three-phase current, with the potential coil on one phase and the current coil taking current from another phase alone or from two phases combined.

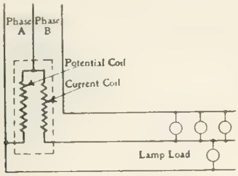


FIG. 503 (a)

This is much more satisfactory than an impedance coil with taps, as any current at any power-factor is readily obtained. Connected as shown in Fig. 503(a) on a two-phase circuit, lamps across phase *A* represent the power component (in phase with the voltage of this phase), and lamps across phase *B* represent wattless component of current in the series coil. The same method is applicable on a three-phase circuit. For information regarding the latter connection see reference in No. 282. A. W. C.

504—Polyphase Power from Single-Phase Circuit Using Synchronous Motor—Please advise whether it would be feasible to operate a polyphase synchronous motor off a single-phase line using an auxiliary motor for starting purposes and taking off polyphase power for operating induction motors, the proposed method of connections being indicated in Fig. 504(a.)

D. W. B. & J. H. K.

It is possible to obtain polyphase power from a single-phase power circuit by connecting a polyphase synchronous motor across the single-phase circuit, using two of the terminals of the polyphase machine for single-phase operation. Such a system is not recommended for general purposes, but may serve in an emergency. The polyphase circuits are liable to be unbalanced in practically the same way as the polyphase circuits are unbalanced on a polyphase generator when single-phase circuits are unbalanced on a true polyphase machine carrying a balanced load, the armature reaction is practically constant in value, while in a single-phase machine the armature reaction is pulsating between zero and the maximum value (See No. 331). When these two reactions occur in the same armature core there is a disturbance of the phase relation of the different circuits. If the polyphase service from such a machine consists very largely of induction motors, they will tend to exert a balancing action and will reduce the unbalancing in phase and voltage in the synchronous motor used thus as a phase transformer. Such a machine has been proposed a number of times for converting from polyphase circuits to single-

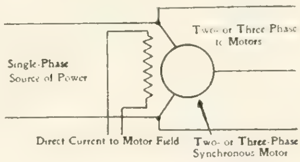


FIG. 504 (a)

phase for railway work, and, by employing certain combinations of reactances in the polyphase circuit, it would appear that fairly well balanced polyphase current conditions could be maintained. However, the machine did not readily permit independent regulation of the voltage on the single-phase side, and therefore was not considered as entirely satisfactory. The monocyclic system, brought out years ago by the General Electric Company, was, to a certain extent, an equivalent of the above synchronous motor used as a phase transformer. In this monocyclic system, each motor, running at normal speed, tended to maintain polyphase relations which assisted in the starting and operation of other polyphase motors on the same system. B. G. L.

505—Speed Adjustment of Shunt Motors—*a*—What percentage increase in speed can be obtained by weakening the fields of 220 volt shunt wound motors of from 15 to 30 hp without commutation trouble? *b*—In the case of a 30 hp motor of standard make would it be possible to secure 50 percent increase in speed without sparking or other trouble? *c*—Please refer me to book or article on speed regulation of direct-current motors where the size of the plant does not warrant the installation of a multiple voltage system? H. K. S.

a—In general 50 percent increase in speed may be obtained on motors of from 15 to 30 hp for intermittent service; the meaning of the latter being that the motor will run at minimum or normal speed for a majority of the time, the maximum speed being required only for short intervals. *b*—A 30 hp motor run at 50 percent above normal speed will probably spark more or less at the brushes, and if run continuously at full load at this maximum speed will more than likely develop blackening, roughening and high mica on the commutator, which will eventually put the motor out of running condition. *c*—The present most satisfactory method of obtaining an adjustable speed motor good for speed adjustment as high as 100 percent above normal or even higher, still maintaining perfect commutation, for continuous service throughout the range, is to provide the ordinary shunt or compound motor with commutating poles. Note No. 168 and references in The Six Year Topical Index of the JOURNAL, pp. 22 and 23; also article on "Commutation and the Interpole Railway Motor," by Mr. J. L. Davis, Oct., 1910, p. 752. F. A. R.

506—Effect of Grounds in Secondaries of Induction Motors—We use a considerable number of squirrel cage type of induction motors, all 220 volt, three-phase machines. I notice that in the G.E. type *I* machines the copper bars and short-circuiting rings of the rotor are insulated from the laminations and from ground in the larger sizes, while in the smaller sizes no attempt is made to do so. By smaller sizes I mean roughly below five hp. In the case of the Westinghouse type C machines of which we also have several, the bars and short-circuiting rings are carefully insulated from the laminations and then grounded on the sides of the laminations at four points with four clips, which seem to serve the purpose of keeping the bars from sliding from side to side. Why should some machines be insulated and others grounded? What are the results and why should one of the insulated rotors become grounded in one or more of the bars? We have a case of a G.E. machine which had a grounded rotor and which ran very hot, threw solder and refused to start under load; upon removing the ground there was no further trouble. Will a different result be obtained if a copper bar be grounded in the laminations instead of by means of the four clips described above? R. B.

Information regarding this question will be found in Nos. 286 and 378. The grounding of rotor bars provided with insulation is probably the result of mechanical vibration. The effect of grounding the rotor winding in the laminations is to produce local circuits in which local currents will be set up. These currents affect the torque, particularly at starting. This should not be noticeable on motors of five hp capacity and smaller, as the rotor voltage is very low in these cases. Circuits which are relatively less local are formed by grounding the resistance rings, and the local currents in these circuits are practically negligible. By grounding the resistance rings at a number of uniformly spaced points equal to one-half the number of poles, no local currents will occur, as these are equi-potential points. On this basis, mechanical braces for the winding of the squirrel cage rotors of motors of large capacity can be provided without introducing trouble due to short-circuit currents.

G. H. G.

THE

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The Field of the Interpole

Of late years the interpole as used on direct-current motors and generators has found an extremely wide application. The employment of the interpole, particularly on variable speed motors, has extended the use of electric drive to conditions which it would have been impossible to meet without that device. Since it has been so successful in the case of direct-current motors and generators, it is only natural to consider its application to synchronous converters. On another page of this issue, Messrs. Lamme and Newbury treat of the use of interpoles in synchronous converters. Their treatment is a very clear one and as such is characteristic of the authors. They show first the fundamental theory underlying the application of the interpole to direct-current machinery in general, and then go on to show that in synchronous converters the inherent need for using interpoles is very small in comparison with their necessity for direct-current apparatus, since the armature reaction in the converter is practically nil.

The final conclusion is that there is no crying necessity for applying interpoles to synchronous converters until the conditions in regard to speed, capacity and other conditions affecting commutation are forced very considerable above what present practice demands. In other words, the conditions so far as commutation is concerned will have to become considerably worse than they are in existing converters, before there will be any real necessity for using commutating poles in such machines.

The matter of interpoles for converters was discussed to considerable extent at the November meeting of the American Institute of Electrical Engineers. At that meeting it was intimated that one of the uses of interpoles would be in connection with synchronous converters to be used with high voltage, direct-current railway systems. In his closing discussion, Mr. Lamme indicated that there was considerable doubt whether or not this use of the interpole was more a logical one than in 600 volt machines. There are conditions other than commutation which enter into the consideration of this matter. It has been found by actual experience that the voltage between adjacent bars in the synchronous converter

should be kept below a certain value, which is dictated not so much by commutating conditions as by a tendency toward flashing on heavy loads and short-circuits and by the fact that the insulation between bars is apt to be injured after a certain maximum voltage between bars is exceeded. Having fixed upon a maximum allowable voltage between bars, the maximum direct-current voltage that it is possible to obtain from a given synchronous converter is merely a matter of the frequency applied to the converter, and the minimum possible width of commutator bars and the maximum possible commutator speed that can be used successfully.

A moment's consideration will show that a given commutator bar must pass from one brush to the next adjacent one in one-half a cycle. Assuming, for example, a commutator speed of 5 000 feet per minute, this consideration makes the distance between adjacent brush arms, twenty inches in a 25 cycle converter and eight and one-third inches in a 60 cycle. If we further assume three-sixteenth of an inch as the minimum that can be occupied by a commutator bar and its insulation, this limits us at once to 106 bars between adjacent brushes in the 25 cycle converter and 44 bars for the 60 cycle. Assuming further that fifteen volts is the limiting voltage between bars, we arrive at once at the conclusion that 1 590 volts is the limiting voltage for a 25-cycle converter and 660 for a 60 cycle. The only way to increase the direct-current voltage is a higher commutator speed, a thinner bar or a higher voltage between bars. Previous practice has shown that the limits mentioned above cannot be very much exceeded.

Further, from the necessity of limiting voltage between bars for reasons other than commutation, it follows at once that the commutating characteristics of the high voltage converter will in general be even better than the low voltage, because there is less current to be reversed in the coil passing under the brush and the self-induction of the coil will not be materially increased, for the reason just mentioned. Apparently, therefore, there is no necessity for using interpoles on synchronous converters simply because they are high voltage machines.

It is questionable, therefore, whether interpoles will ever be used in synchronous converters to the same extent that they are used on direct-current machines and further the conditions which might demand their use, such as higher speeds, larger outputs per pole, etc., must considerably exceed anything demanded at present before they will be advisable at all. P. M. LINCOLN.

From Torch to Tungsten

A few days ago I saw an historical exhibit of about a dozen lamps, beginning with the pine torch at one end and ending with the tungsten filament lamp at the other. Until less than a hundred years ago, torches, candles and animal and vegetable oil held the field. Then came gas and later kerosene. Some thirty years ago the carbon incandescent lamp was introduced, followed very recently by the tungsten lamp. The legend on the exhibit showed a decrease in cost per candle-hour from a quarter of a cent for the candle of our grandmothers to one eightieth of a cent for the latest lamp.

All of these older lamps have a common element—carbon. It was the carbon of the pine stick, of the candle, of the oil and the gas which was heated to incandescence in the flame. Likewise the two kinds of electric lamps in common use a few years ago were carbon lamps; the carbon filament incandescent lamp and the carbon electrode arc lamp.

Suppose that you, an ordinary, practical man concerned more with the using than the making of lamps, had undertaken ten years ago to specify a new and improved lamp, what would you have called for? Being familiar only with the incandescent filament in a vacuum and the arc in the air, and unless gifted with scientific imagination, it is hardly likely that you would have thought of an incandescent rod in the air like the Nernst lamp, or of an arc in a vacuum, a form which the Cooper-Hewitt lamp suggests. Presumably you would first have made choice between the incandescent type and the arc type and then have indicated the particular characteristics desired. Possibly your thoughts might have been expressed somewhat as follows:—

The ideal lamp is an incandescent lamp, as it has no external mechanism, nor moving parts; as it is small, convenient, requires no attendance and can readily be handled by anybody; as the heated portion is enclosed and protected from contact with inflammable materials; as the heat given off is small; as no gas is produced and the lamp is not affected by dampness and fumes. It is inherently steady, giving a uniform light, as it has no automatic adjusting device. It may be operated on either multiple or series circuits, either by direct or by alternating current, at different frequencies, and on alternating current it has a power-factor of one hundred percent. The initial wiring and fixtures may be of the simplest

form; as there is no external regulator or mechanism, no investment is required for auxiliaries, and there is little or nothing to get out of order or out of date and be thrown away if changes in conditions make necessary a re-arrangement of the lighting. The incandescent lamp may be placed in any position and is admirably adapted to reflectors for securing an efficient application or a uniform distribution of the light and it lends itself to artistic designs.

The new lamp should, therefore, be an incandescent lamp, having the foregoing general characteristics. It should be adapted for the ordinary standard voltages on multiple circuits or for currents which have been found well adapted for series operation. The ideal lamp should have a wide range in candle-power covering the wide gap between the ordinary carbon incandescent lamp and the arc lamp, as one usually is not made larger than say 32 candle-power and the other is not made smaller than 500 or 1 000 candle-power. The different sizes should be adapted for operation from the same circuits, so that large or small lamps of the same type and appearance can be employed in the different parts of the same installation. The new lamp should give a light of a white quality approximating daylight. Its filaments should be definitely and compactly located in the bulb, making it readily adapted to reflectors which can accurately distribute the light. The ideal lamp should have a minimum variation in candle-power with variation in voltage. It should have minimum change in color over a wide range in voltage. It should have a practically uniform candle-power over a long period of time. It should give fair illumination under abnormally low voltage and it should not be destroyed by the momentary application of a very high voltage. The efficiency should be high and it should maintain practically constant efficiency throughout its useful life. The quality of its light should be satisfactory at different efficiencies so that the efficiency at which it is operated may be selected in accordance with the cost of current, in order that the total cost of current and of lamp renewals may be a minimum. Its normal life should be long. The first cost of the lamp should, of course, be such that the operating cost, consisting of cost of renewals and the cost of current, may be low.

The essence of such a specification is that the ideal lamp should possess the excellent general features of the carbon incandescent lamp; that it should be an improvement upon it in

such matters as quality of light and sensitiveness to variations of voltage; that it should be more efficient, cheaper to operate and maintain a high efficiency throughout a longer life, and in particular, that it should be available in a wide range of sizes, thus making it practically a universal illuminant.

Granting that such a specification as this would have been generally approved ten years ago, although it might have been regarded as an unattainable ideal, it is interesting to observe how completely the tungsten filament lamp meets the ideal specification. When one considers the long list of good qualities which the new lamp possesses he does not wonder that it has so quickly come into such wide and acceptable use. So good is the lamp that one almost overlooks the few points in which it does not reach the ideal. True, it is not available in very small sizes for 110 volts, the finer filaments show a slight flicker on 25 cycles, the lamp had, at first, an unenviable reputation for fragility, and its high intrinsic brilliancy permits a misuse of the lamp which is a crime against eyesight. Improvements in methods and manufacture, however, have been and are being made. Commercial units of much smaller sizes are now available than formerly. Improved processes and new methods are producing lamps that show very little breakage in ordinary use. People in general are learning how to place lamps and how to use reflectors so as to avoid the evils of direct light from the bright filament.

The notable progress of the tungsten filament lamp in this country has not been the simple and direct replacing of carbon lamps by new lamps of whiter light and better efficiency, but it has been the development of a new field for incandescent lighting by use of larger units. Stores, offices, factories and public halls in which the small carbon lamp was too small, and in which the arc lamp was unsatisfactory because the intensity was too great, are now admirably lighted by the tungsten filament lamp of intermediate size. This new field of incandescent illumination has compelled attention to the matters of proper and efficient distribution of light. It has led to the sudden springing up of a scientific, an engineering and a commercial interest in illumination, and the inauguration of illuminating engineering.

All this has been brought about through scientific researches which have found a rare metal whose temperature can be maintained at a far higher value than is possible with the carbon filament.

CHAS. F. SCOTT

Seven Years of the Journal

On completing its seventh volume, the JOURNAL may properly take a retrospective glance to see what has been accomplished. Its ideal has been to enter, or rather create, a field somewhat different from current scientific or technical journals on the one hand and the transactions of a learned society on the other. It had no traditions to restrict and it was free to shape its own course. It could be as elementary as it chose and it could deal with matters obstruse and perplexing. Its direct aim was to deal with things which are useful and important; to treat in a simple, direct way, of the apparatus and the engineering questions which are of present interest and value; to bring together from men in active contact with electrical and allied industries, the latest information and views in such a way as to be useful to others. The expert must know his subject and be so far advanced in it that it is often difficult or impossible for others to follow. Sometimes his method is mathematical analysis. Sometimes it is painstaking experimentation and investigation. However, the results can usually be stated in plain language in such a way that the essentials can be understood by others. Such a method is admirably illustrated in the paper by Messrs. Lamme and Newbury appearing in this issue of the JOURNAL.

During the past seven years, much has happened electrically. Seven years ago there was no underground electric traction in New York City. Now there are great subway, rapid transit systems; there are two great railway terminals electrified, and the City is reached by a dozen under-river electric tunnels. During this period many thousand of young men have entered the increasing field of electrical work through the technical colleges and the school of experience. The JOURNAL has recognized that it could be particularly helpful by aiding these young men to gain the simple, direct, practical information which would bring to them the results of the experience of others, particularly with regard to the new apparatus and the new methods which have not yet found their way into the text-books.

A large proportion of the articles now deal with questions of the application and use of electric power. Some give specific information, and practically all indicate methods and results in the growing field of commercial engineering.

Supplementing the more professional articles, the JOURNAL has presented suggestions and counsel from men of experience and

large views. The contributions by the late Walter C. Kerr, for example, can be read and re-read with profit.

Of late the JOURNAL has been getting in closer touch with its readers by responding to their queries and thus furnishing a remarkable fund of expert information on particular subjects such as are the cause present difficulties. Over five hundred questions and answers have been printed in the Question Box. The list, printed in this issue, of those who have contributed replies, shows that the Question Box does not have to depend alone on the knowledge of two or three editors but has drawn upon over seventy-five experts during the year.

That the JOURNAL has been unusually successful in realizing its aim in a manner acceptable to its readers is indicated by a few facts which may be of general interest:—

During the past year 90 percent of the expiring subscriptions have been renewed and new subscriptions have been added to the list until it is now twenty percent greater than it was a year ago. The JOURNAL has supplied 7 200 bound volumes of its first six years making a number sufficient for 1 200 sets. The demand for these sets still continues although the first two volumes are no longer available.

During the present year the number of reading pages aggregates 998, which is 30 percent more than the preceding year, and 50 percent more than the first year. The total number of reading pages in the seven volumes is about 5 500, all of which is covered by its annual up-to-date topical index, a feature which we believe to be original with the JOURNAL.

The widening field of electrical interests, the importance and use of electrical appliances, the larger relations of the electrical engineer to other branches of engineering and to public affairs, give a breadth of field which imposes increasing difficulty in shaping the editorial course so that the JOURNAL may be acceptable to its widening list of readers. The increased size is helpful, and the aim of treating each subject in such a way that it may be readable both by those who are experts and by those who are relatively uninformed, serves to give specific information and at the same time promote that broadening of information and interest which is essential to the engineering profession.

The direct, personal interest of our readers will aid the editors, who always welcome suggestions as to how they may make the publication still more valuable to its subscribers.

INTERPOLES IN SYNCHRONOUS CONVERTERS*

B. G. LAMME and F. D. NEWBURY

A DISCUSSION of the question of interpoles in synchronous converters naturally suggests a comparison with interpoles in direct-current generators. Interpoles have been used very generally in direct-current machines, both in the United States and in Europe, and in converters only to some extent in Europe. Has this been due to lack of sufficient advantage in converters or to a lack of appreciation on the part of American engineers? The synchronous converter and the direct-current generator are two quite different machines in their characteristics, and no one can say off hand that interpoles will give the same results in both. In the following is given a partial analysis of the conditions occurring in the two classes of machines, which will indicate wherein interpoles are of greater advantage on direct-current generators than on converters.

Taking up, first the direct-current generator, the magnetomotive force of the armature winding has zero values at points midway between two adjacent brush arms or points of collection of current and rises at a uniform rate to the point of the winding which is in contact with the brushes, as shown in Fig. 1. Therefore, the armature winding has its maximum magnetizing effect at that part of the core surface where the winding is directly connected with the brushes. However, the presence of a larg air-gap at this same point may mean a relatively small magnetic flux, while a much higher flux may be set up by the armature winding at other places due to lower reluctance. In the usual direct-current generator construction without interpoles, the position of commutation is almost midway between two adjacent poles and therefore the point of maximum magnetomotive force of the armature is also practically midway between poles. The absence of good magnetic material over the armature at this point serves to lessen the magnetic flux due to the armature magnetizing effect, but even with the best possible proportions there will necessarily be a slight magnetic flux set up at this point. While this field is usually of small value, yet unfortunately it is of such a polarity as to have a harmful effect on the commutation of the machine.

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*Condensed from a paper read before the American Institute of Electrical Engineers, November 11, 1910.

If the short-circuited coil at the moment of commutation is moving across a magnetic flux or field, it will have an e.m.f. set up in it which will tend to cause a local or short-circuit current to flow. Such a current is set up by the flux due to the armature magnetomotive force described above, and fortunately this current flows in such a way as to give the same effect as an increased external or working current to be reversed as the coil passes from under the brush. In other words, the e.m.f. set up in the short-circuited coil by the above field adds to the e.m.f. of self-induction in the coil due to the reversal of the working current.

Another cause of difficulty in the commutation of a direct-current machine is the self-induction of the armature coils, as they individually have the current reversed in them in passing from one side of the brush to the other. During the act of commutation, that part of the local field due to the coil which is being commutated must be reversed in direction. It is therefore desirable to make the local field due to any individual coil as small as possible. This means that the number of turns per coil should be as low as possible, while the magnetic conditions surrounding the coil should be such as to give the highest reluctance. By the proper arrangement of the various parts, it is usually found that the e.m.f. of self-induction, due to the reversal of the coil passing under the brush, can be made of comparatively small value so that, if no other conditions interfere, good commutation can be obtained under practically all commercial operating conditions. But, the magnetic field between the poles, set up by the armature magnetomotive force as a whole, as described above, adds very greatly to the difficulties of commutation. If the armature magnetomotive force, or the field due to it, could be suppressed, then one of the principal limitations in the design and operation of direct-current generators would be removed, and the commutation limits would be greatly extended. Or, better still, if a magnetic flux in the reverse direction were established at the point of commutation, then the e.m.f. set up by this would be in opposition to the e.m.f.

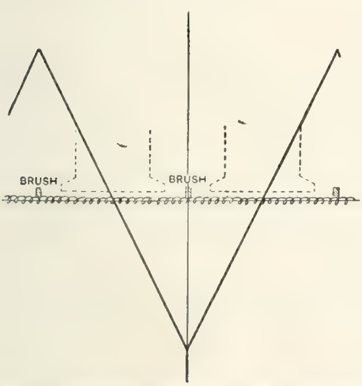


FIG. 1—CURVE SHOWING MAGNETOMOTIVE FORCE OF ARMATURE OF A DIRECT-CURRENT GENERATOR

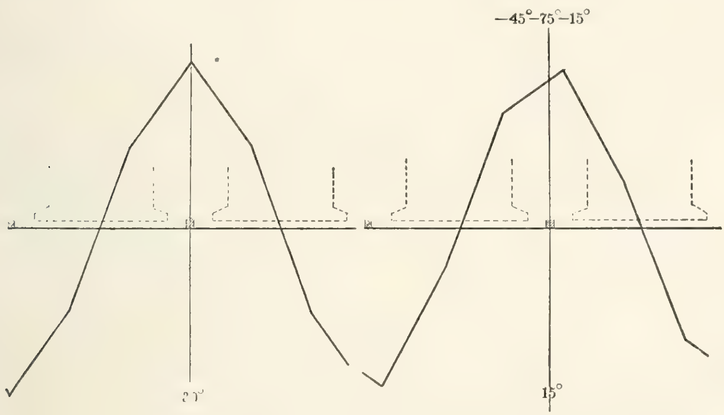
of self-induction of the commutated coil and would actually assist in the commutation.

This latter is what is accomplished by interpoles. When these are used the brushes on the commutator are so placed that the short-circuited or commutated coils are directly under the interpoles. Consequently, the maximum magnetomotive force of the armature is in exact opposition to that of the interpoles. Therefore, the total ampere-turns on the interpoles should be equal to the total ampere-turns on the armature in order to produce zero magnetic flux under the interpole or at the point of commutation. But for best conditions there should not be zero field, but a slight field in the opposite direction from that which the armature winding alone would produce. Therefore, the magnetomotive force of the interpole must be greater than that of the armature by an amount sufficient to set up a local field under the interpole which will establish an e.m.f. in the short-circuited coils opposite to that set up by the commutated coils themselves and practically equal to it. The excess ampere-turns required on the commutated poles is therefore for magnetizing purposes only and the amount of extra ampere-turns will depend upon the value of the commutating field required, the depth of air-gap under the commutating poles, etc. The commutating field required is obviously a function of the self-induction of the commutated coil and evidently the lower the self-induction the less commutating field will be required. It is evident, therefore, that the commutating field under the commutating pole bears no fixed relation to the armature ampere-turns or to the main field ampere turns, but is, to a certain extent, dependent upon the proportions of each individual machine.

It is evident that the magnetomotive force of a given armature varies directly with the current delivered regardless of the voltage. Therefore, that part of the interpole magnetomotive force which neutralizes that of the armature should also vary directly in proportion to the armature current. Also, the self-induction of the commutated coils will vary in proportion to the armature current carried, and therefore the magnetic field under the interpole for neutralizing this self-induction should also vary in proportion to the armature current. It is therefore obvious that if the main armature current be put through the interpole winding, the magnetomotive force of this winding will vary in the proper proportion to give the correct commutating conditions

as the armature current varies, regardless of the voltage of the machine. This is on the assumption that the entire magnetomotive force of the interpole winding is effective at the air-gap and armature, which implies an absence of saturation in the interpole magnetic circuit. In the usual construction, the interpole winding always carries the main armature current as indicated above.

The synchronous converter differs from the direct-current generator in one very important particular, namely, it may be considered as motor and generator combined. It receives current from a supply system the same as a motor and it delivers current to another system like a direct-current generator. The magnetomotive force of the armature winding as a motor acts



FIGS 2 AND 3—DISTRIBUTION OF ALTERNATING-CURRENT MAGNETOMOTIVE FORCE ON SIX-PHASE SYNCHRONOUS CONVERTER FOR DIFFERENT POSITIONS OF ARMATURE

in one direction, while the magnetomotive force of the armature winding as a generator acts in the opposite direction. As the input is practically equal to the output, it is evident that these two armature magnetomotive forces should practically neutralize each other, on the assumption that the armature magnetomotive force, due to the polyphase current supplied, has practically the same distribution as that of the corresponding direct-current winding. Assuming that the two practically balance each other, then it is evident that one of the principal sources of commutation difficulty in direct-current generators is absent in the converter and therefore the limits in commutation should be much higher than those of direct-current machines.

The diagrams, Figs. 2, 3 and 4, show the distribution of the alternating-current magnetomotive forces on a six-phase rotary converter. This is plotted for three different positions of the armature displaced successively 15 electrical degrees. The general forms of these distributions repeat themselves for further similar displacements, as indicated by the angles over Figs. 3 and 4.

It is evident from these figures that the peak value of the magnetomotive force of the armature varies as the armature is rotated, as indicated by the heights of the center line in the three figures.

In Fig. 5, the magnetomotive force distribution of Fig. 2 and the corresponding direct-current distribution of Fig. 1 are both

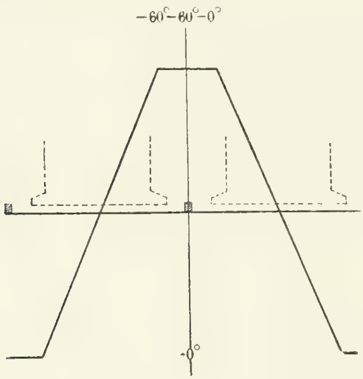


FIG. 4—DISTRIBUTION CURVE CORRESPONDING TO THOSE OF FIGS. 2 AND 3 BUT WITH ARMATURE STILL FURTHER DISPLACED

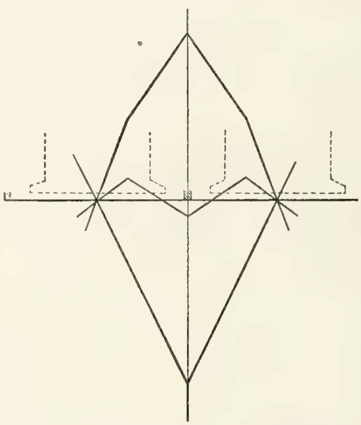


FIG. 5—DISTRIBUTIONS OF FIGS. 1 AND 2 SHOWN IN OPPOSITION WITH THE RESULTANT OF THEIR COMBINED EFFECT

shown, but in opposition to each other. In this figure both are shown in proper proportion to each other, taking into account the alternating-current and the direct-current output. The resultant of these two distributions is also indicated in these figures.

In Fig. 6 the distributions correspond to Figs. 3 and 1 combined and the resultant is also shown. Fig. 7 combines Figs. 4 and 1.

It is the resultant magnetomotive force in these three figures which is important, as this is the effective magnetomotive force which tends to produce a flux or field over the commutated coil. This resultant varies in height as the armature is rotated, but the

maximum is only a relatively small percent of the direct-current magnetomotive force. Therefore, one of the principal sources of difficulty in commutation by the direct-current generator is practically absent in the converter.

The resultant magnetomotive force of a synchronous converter might be compared with that of a direct-current generator with compensating windings in the pole faces. It is generally known that such direct-current generators have much better commutating conditions than ordinary uncompensated machines. If such compensating winding on the field of a direct-current machine covered symmetrically the whole armature surface, then the armature reaction could be completely annulled, which is not

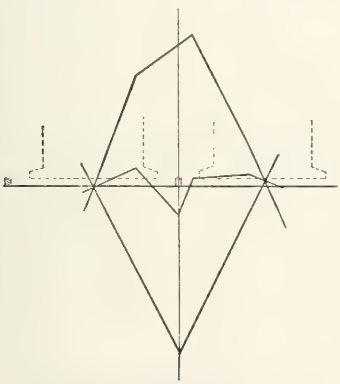


FIG. 6—DISTRIBUTIONS OF FIGS 3 AND 1 COMBINED IN OPPOSITION AND THEIR RESULTANT

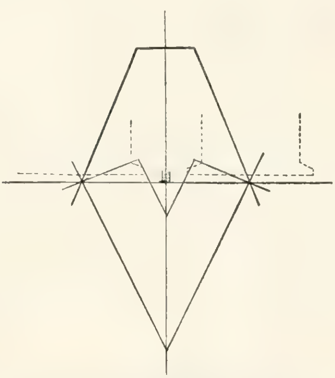


FIG. 7—DISTRIBUTIONS OF FIGS. 4 AND 1 COMBINED AND THEIR RESULTANT

the case in the converter. But with compensating windings located only in the pole faces, then the armature magnetomotive force midway between the poles could not be completely annulled and the resultant would be as shown in Fig. 8, which is not quite as good as the average resultant in the converter. The commutating conditions in the converter can therefore be considered as at least as good as in a direct-current generator with a compensating winding of normal value located in the pole faces only.

In the application of interpoles to the synchronous converter the same principles should hold as in a direct-current generator, namely, the interpole magnetomotive force should be sufficient to neutralize that of the armature windings and, in addition, should

set up a small magnetic flux sufficient to overcome the self-induction of the commutated coil. As the magnetomotive force of the armature varies between seven and 20 percent in the above figures, it is evident that perfect compensation cannot be obtained and that therefore only some average value can be applied. Assuming that 15 percent will be required on the average to compensate for this, then in addition the interpole winding must carry ampere-turns sufficient to set up the small magnetic field for commutation. Thus the total ampere-turns on the interpole will be equal to 15 percent of the armature direct-current ampere-turns plus a small addition for setting up the useful or commutating field. In the direct-current generator, the ampere-turns on the interpoles must equal the total armature ampere-turns plus a corresponding addition for the commutating field. It is therefore evident that an interpole winding on a converter will naturally be very much smaller than on a direct-current generator, and in general it is between 25 and 40 percent of the direct-current, interpole winding.

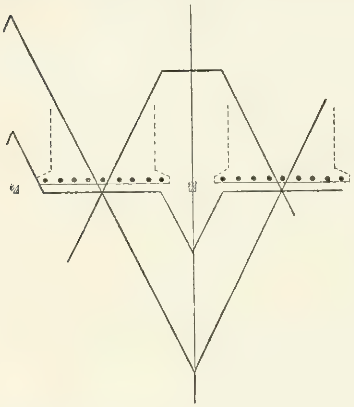


FIG. 8—SHOWING RESULTANT MAGNETOMOTIVE FORCE OF DIRECT-CURRENT GENERATOR WITH COMPENSATING WINDING IN THE POLE FACES

Due to the relatively small number of ampere-turns required on the interpole of a converter compared with those required on a direct-current generator, the design of the interpoles in the two cases presents quite different problems. In the direct-current generator the interpoles carry ampere-turns which are in all cases greater than the armature ampere-turns. As the field ampere-turns on the main poles are not infrequently but little greater than the armature ampere-turns, it is evident that the interpole winding may, in some cases, carry as many ampere-turns as the main field windings. While but a small percent of these interpole windings is effective in producing flux under the pole tip, yet they are all effective in producing leakage from the sides of the poles.

In the synchronous converter the conditions are somewhat different, due to the fact that the interpole ampere-turns are usually only 25 to 40 percent as great as on a corresponding direct-

current generator. The leakage at the sides of the poles becomes relatively much less, while the useful induction remains about the same as on the direct-current generator. In consequence, saturation of the poles is not so difficult to avoid.

In some cases it may be impracticable to get exactly the right number of turns on the interpole winding to give the correct interpole magnetomotive force. The extra current might be shunted. A non-inductive shunt, however, is bad. If an inductive shunt is used, instead of non-inductive, and the reactance in this shunt circuit is properly adjusted, then it is possible to get the right interpole strength for normal conditions and still obtain satisfactory conditions with sudden changes in load.

Another condition which may affect the action of interpoles on converters, but which does not occur in direct-current generators, is hunting. During hunting the resultant magnetizing effects of the alternating current and direct current do not nearly neutralize each other at all times, and the interpole winding will not be correctly proportioned at all times.

It is evident that under such condition the presence of an interpole may give much worse results than if no interpole were present; for the reason that if there is a magnetomotive force in the wrong direction at the interpole, the interpole magnetic circuit apparently makes conditions worse. In consequence, an interpole synchronous converter should be especially well designed to avoid hunting.

In direct-current generators and motors interpoles have been of great advantage, due to variable speed and variable voltage requirements. In synchronous converters, however, the requirement of variable speed is obviously absent and that of variable voltage very limited The converter has constant voltage characteristics and variable voltage can only be obtained through the agency of such relatively expensive devices as induction regulators, synchronous boosters or split-pole constructions. The advantages of interpoles in synchronous converters are then to be looked for only in the direction of increased outputs and higher speeds.

It will be instructive, before considering the possibility of advance in this direction, to take a brief survey of what has been accomplished without interpoles. The data of some machines of large output and high speed which have been built and placed in operation in the United States are given in Table I.

The ratings given in Table I are plotted in curve form in

Fig. 9, to which have been added other ratings which have been proposed and which can obviously be built in view of their relation to ratings which have been built. Fig. 9 represents concisely the situation today as far as the writers are familiar with it. The curves bring out very nicely the relation between permissible amperes per brush arm and frequency and voltage. It will be noted that the permissible current is greater in the 250-volt converters than in the 600-volt converters, and greater in the 25-cycle converters than in the 60-cycle converters of the same voltage.

25-Cycles, 250-Volts—Due to the low frequency, low commutator peripheral speeds are possible without exceeding very con-

TABLE I.

Kw	Volts	Poles	Rev. per min.	Cycles	Amperes per brush arm
3000	600	16	187	25	625
2000	250	18	167	25	889
1000	250	10	300	25	80c
800	250	8	375	25	800
1000	250	14	514	60	570
500	250	10	720	60	400
1000	600	12	600	60	278
500	600	8	900	60	208
300	600	6	1200	60	167

servative limits in distance between neutral points and voltage between adjacent commutator bars. This permits very long commutators, without exceeding safe mechanical limits. The large currents due to the low voltage require at best a large number of poles, which results in a low speed in revolutions, and which also simplifies the mechanical problem of the commutator design. The large currents to be handled, particularly in the larger outputs, make it desirable to push to the limit the current per brush arm. The permissible current per brush arm is high, due to the favorable conditions mentioned above and the result is seen in the high values of amperes per brush arm used in converters of this class. It is evident that for converters of low voltage and low frequency the limit to further increase in speed—with consequent decrease in poles —is *the length of commutator* rather than sparking.

25 Cycles, 600 Volts—As in the 250 volt converters, low frequency permits low commutator peripheral speed which, in turn, permits relatively long commutators. The smaller currents to be handled, however, permit fewer poles, which results in higher speeds than in the corresponding 250 volt converters, which necessitates somewhat shorter commutators. The result is that, due to the higher speeds, the limit in amperes per brush arm is lower than in the 250 volt converters. By comparing the curves for 25 cycle, 600 volts, and 60 cycle, 250 volts in Fig. 9, it is evident that somewhat higher values of amperes per brush arm could be used for the former, since for the same kilowatts and speed the amperes per brush arm are equal. Either the highest available speed has not been employed in existing designs, or higher speeds could be used if

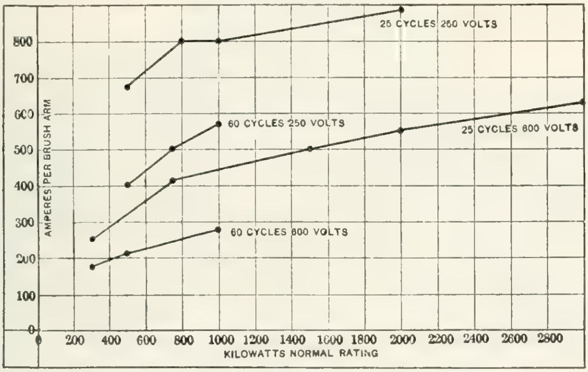


FIG 9—CURVES SHOWING DATA OF TABLE I

interpoles were added. With these converters the limits to further increase in speed is not the length of the commutator.

60 Cycles, 250 Volts—The maximum possible speed at the commutator is used in order to increase the space between neutral points, and the number of poles are chosen as small as possible without exceeding questionable operative speeds. This imposes very severe mechanical conditions in the commutator design. Going as far in this direction as is represented by the ratings mentioned above, the number of poles is still larger than would be selected in a direct-current generator of the same rating. The amperes per brush arm are smaller than in the 25 cycle converters of the same voltage, due to the larger number of poles imposed by the frequency requirement.

We question, however, whether higher speeds and greater

amperes per brush arm are possible without radically changing the present type of commutator construction. Here, then, as in the low-freqency, low-voltage converters, the barrier to higher speeds is found in the commutator mechanical design rather than in the electrical design.

60 Cycles, 600 Volts—As in the 250 volt, 60 cycle converters, the number of poles is made as small as possible, keeping within permissible speeds, but, with the small currents handled in 600 volt converters and the larger number of poles necessitated by the high frequency, the amperes per brush arm as shown by Fig. 9 are very low.

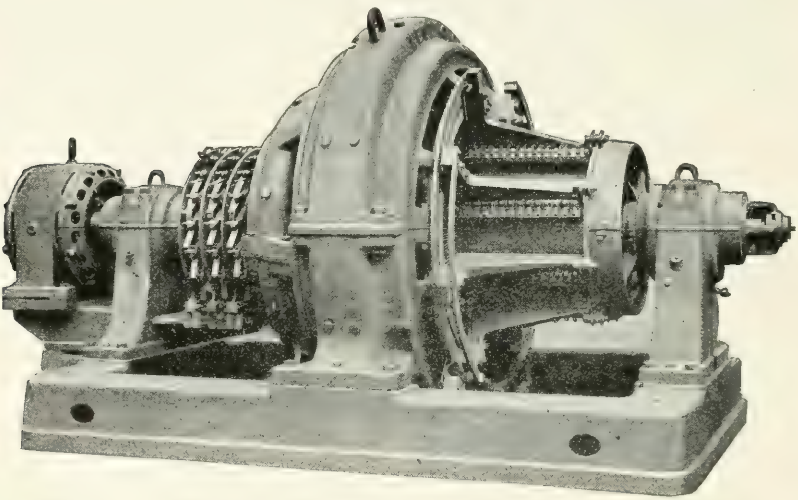


FIG. 10—ILLUSTRATING DESIGN OF HIGH SPEED SYNCHRONOUS CONVERTER WITH LONG COMMUTATOR SUITABLE FOR HEAVY CURRENTS
800 kw, 250 volt, 3 200 ampere, 25 cycle, 8-pole, 375 r.p.m.

The limit to higher speed is obviously not amperes per brush arm. Interpoles would probably permit higher speeds due to more favorable sparking conditions, but higher speeds than those now used would certainly require changes in present commutator designs.

To summarize the above discussion of the various limits to increased speed:—It would appear that 25 cycle, 600 volt converters offer the most promising field for the application of interpoles; that 60 cycle, 600 volt converters follow next and that 60 cycle and 25 cycle 250 volt converters show the least possibilities of improvement from the standpoint of design.

A serious objection to the use of shrink-ring commutators is the difficulty of making repairs on them after installation. This, in general, limits the use of shrink-ring commutators to machines in which other constructions cannot be employed.

Granting that increased speeds are feasible through the use of interpoles, and that it is possible to build satisfactory commutators at the increased speeds and increased current outputs, the question still remains whether such a change results in a sufficient reduction in cost or improvement in performance to warrant the change. Considering 25 cycle, 600 volt converters, it is possible to build a 300 r. p. m., 1 500 kw converter without interpoles of a design in line with conservative practice. There is ample basis for the belief that still without interpoles, the speed could be increased to 375 r. p. m., without sacrificing good commutating limits, and that, with interpoles and, assuming, that a satisfactory commutator could be designed and built, the speed could be further increased to 500 r. p. m. But, comparing the material required in the eight-pole 375 r. p. m. converter and in the six-pole 500 r. p. m. converter, it will probably be found that the cost of the six-pole machine of such large capacity is as great as or greater than the eight-pole. It is also questionable whether the 750 kw size which is now built with six poles for 500 r. p. m. could be changed to four poles and 750 r. p. m. with a decrease in cost sufficient to warrant the change.

Considering 60 cycle converters, both 600 and 250 volt, any increase in speed would result in machines comparable with direct-current turbo-generators in type of construction and in cost. To state the matter conservatively, it is extremely doubtful whether any material increase in speeds above those now known to be possible without interpoles can be made with enough saving in cost to compensate for the expense of adding interpole windings, if such are required.

The advantages and disadvantages chargeable to interpoles may be summarized as follows:—

1—Assuming that considerably higher speeds could be used: *Advantages*—*a*—Possible reduction in cost. *b*—Less attention required in operation. *c*—Longer life of commutator and brushes. The advantages *b* and *c* may be more than counterbalanced under the present assumption, by the greater difficulty of maintaining

any commutator in proper condition with the higher speed assumed.

Disadvantages—*a*—Possibility of increased trouble from bucking on sudden changes in load or short-circuit. *b*—Possible reduction in efficiencies, particularly in light load. *c*—Higher operating temperatures unless the same temperatures as now obtained in non-interpole machines are maintained by partly sacrificing the advantage of lower cost.

2—On the assumption that no higher speeds will be used with interpoles than have been found to be practicable without interpoles, but that the interpoles will be added simply as a refinement to machines that would operate satisfactorily without them.

Advantages—*a*—Less attention required during operation. *b*—Longer life of commutator and brushes.

Disadvantages—*a*—Possibility of increased trouble from bucking on sudden changes in load or short-circuits. *b*—Slightly lower efficieencies. *c*—Higher operating temperatures. *d*—Greater cost due to the addition of interpoles.

This is true, of course, only with the stated assumption that the converter is designed to operate satisfactorily without interpoles. It would probably be possible to design a converter with interpoles without exceeding the cost of the non-interpole machine, as has been done in other types of apparatus, but this would be done by making a machine which is unsatisfactory without interpoles and then improving the commutating conditions by interpoles. Such results, however, would hardly represent an improvement over present practice.

CONCLUSION

The authors have attempted to state the case for and against interpoles in all fairness. From the standpoint of design it seems difficult to make a sufficiently strong case for interpoles in synchronous converters to warrant the additional complication in construction. At best the addition of interpoles, properly applied, represents a refinement over present designs, and the fundamental question is whether such refinement is justified commercially. This question, however, must be decided, as all engineering problems are finally decided, not by the judgment of one man or any group of men, but by the results of experience in extended operation.

WEIGHT EQUALIZATION ON LOCOMOTIVE WHEELS

G. M. EATON

THE successful operation of a locomotive is dependent among other features upon its ability to run over track of ordinary construction with only a small variation in the distribution of weight on the various wheels. A wheel that loses a large portion of its normal load when passing over a low spot in the track is liable to derail. On the other hand, a wheel that assumes excessive weight when climbing up on a high spot will tend to damage the track. The mechanical means for approximating a constant weight distribution is called the equalizing system.

There are two classes of weights on every locomotive wheel, viz., dead weights and spring born weights. The dead weights are those that are supported directly by the rail without the interposition of springs. They usually consist of the wheels and axles, the journal boxes and certain parts of the equalizing system. In steam locomotives the side rods and often parts of the valve gear are also dead weights. In the earliest electric locomotives the gears and parts of the motors were usually dead weights on the rails. In certain locomotives of more recent design the motors do not come under this category.

The spring born weights, as the name implies, are supported by the rails through springs and it is only the spring born weights with which the equalizing system is directly concerned.

FUNDAMENTAL PRINCIPLES

For the best operation, it is essential that the spring born weights ride on an even keel, so to speak. That is, they must move in a plane approximately parallel to the rails without any permanent displacement either transversely or longitudinally. When these weights are temporarily displaced by track irregularities they must tend to return to their normal position as soon as the disturbing forces are removed.

Illustrations—There are several types of rigid structures which satisfy some of the fundamental principles, but there is only one which inherently embodies all the necessary features.

A sphere standing on a horizontal surface will be in a state of stable equilibrium and will exert a constant force upon the supporting surface. If it is moved in any direction, however, there is no tendency for it to return to its normal position and as soon as

the supporting surface is tilted in any direction the sphere is no longer in a state of stable equilibrium, but will move.

When a dumb-bell rests upon a horizontal surface, the two points of contact will sustain equal weight as at *1* and *2* in Fig. 1. Even when the supporting surface is tilted about an axis at right angles to the axis *LM* of the dumb-bell as in Fig. 2, the weight W will still be supported about equally upon the points *1* and *2* as long as the angle *A* is small. If one end of the bell is lifted from the supporting surface as in Fig. 3, it will resume its normal position as the distrurbing force is removed. If, however, the supporting surface is tilted about an axis other than the one noted, the bell will roll and when the surface is brought back to the horizontal there will be no tendency for the bell to resume its original position on the plane.

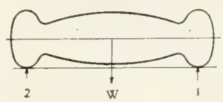


FIG. 1

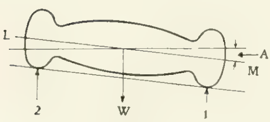


FIG. 2

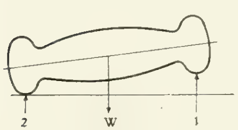


FIG. 3
TWO POINTS OF CONTACT

The structure which inherently embodies the fundamental principles for an ideal equalization is the three-legged stool as shown in Fig. 4. In this structure the weight *W* is supported evenly by the contact points *1*, *2* and *3*, not only when the supporting surface is level but also when it is slightly tilted in any direction. If any one of the legs is raised from the surface of support the stool will return to its normal position upon the removal of the disturbing force. It may be possible to make a stool with four legs which will equally distribute the weight upon the four contact joints, but commercially it is only a matter of chance that this can be done, as can be easily illustrated by experimenting with a heavy four-legged chair on an ordinary rough floor. It will be found that the chair will teeter over two legs, coming to rest on these two and one other, with the fourth out of contact. Usually after numerous trials a location on the floor can be found where the four legs will be in contact, but even then the distribution of the weight on the four legs is indeterminate. An equalizing sys-

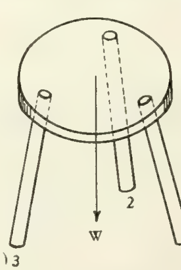


FIG. 4—THREE POINTS OF CONTACT

tem based upon the principle of the three-legged stool is usually termed a three-point equalization.

LOCOMOTIVE EQUALIZATION

It is, of course, impracticable to support a locomotive with only three points of contact on the rails. Several wheels may, however, be equalized together in such a way that they constitute what is termed a single point of equalization. Figs. 5, 6, and 7 illustrate a grouping of wheels constituting a single equalization point.

1 and *2* are the wheels.

3 and *4* are the journals, shown in this case inside of the wheels.

5 and *6* are the journal boxes.

7 and *8* are the spring saddles. They stand on top of the journal boxes and straddle over the locomotive side frame, *25*.

9 and *10* are the semi-elliptic springs.

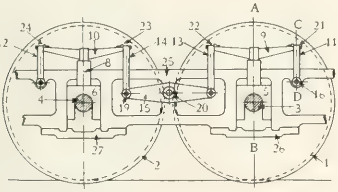


FIG. 5
SINGLE POINT OF EQUALIZATION

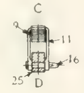


FIG. 6
SECTION CD

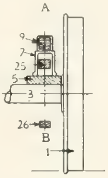


FIG. 7
SECTION AB

11 and *12* are the spring hangers. These are secured at their lower ends to the side frame *25*. They are U-shaped in this particular construction as shown in Fig. 6.

13 and *14* are also spring hangers, secured at their lower ends to the equal beam, *15*.

15 is called an equal beam. The ends are secured to the hangers as above noted and the center is secured by a hinge pin *20* to the side frame *25*.

16 and *17* are pins connecting *11* and *12* to the side frame *25*.

18 and *19* are pins connecting *13* and *14* to equal beam *15*.

20 is a pin connecting the equal beam *15* to the frame *25* as above noted.

21, *22*, *23* and *24* are saddles arranged to keep the spring hangers from slipping off of the springs.

Fig. 8 shows diagramatically the distribution of the spring born weights upon the equalizing system, all weights being considered statically. Assume *W* to be the total spring born weight which is applied on the wheels *E* and *F* and that it is desired that each wheel carry one-half of this weight or $\frac{W}{2}$ then the loads on top of the journal boxes *A* and *B* are the same and each equals $\frac{W}{2}$. The two ends of the semi-elliptic springs are of equal length and, therefore, $C = D = \frac{W}{4}$ since $C + D = \frac{W}{2}$ In the same way $G = H = \frac{W}{4}$. It is evident that $K = D + G = \frac{W}{2}$

Assume that the wheel *E* is raised by a high spot in the track as shown in the dotted position at E^1 in Fig. 9. In order to make

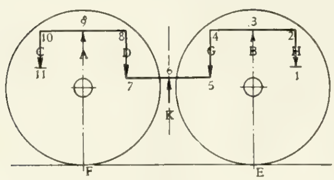


FIG. 8

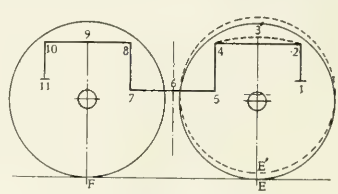


FIG. 9

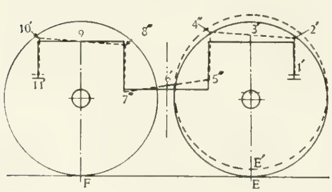


FIG. 10

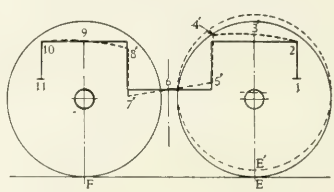


FIG. 11

DIAGRAMS ILLUSTRATING ACTION OF SINGLE POINT OF EQUALIZATION

an analysis of the positions assumed by the various parts, it will be best to first consider the entire structure as rigidly maintained in position and then release one item after another. The elevation of the wheel *E* will then deflect the spring *2*, *3*, *4*, the ends *2* and *4* remaining at the same level as in normal position and the point *3* rising to the point *3'* as shown by the dotted line. Examining the equal beam *5*, *6*, *7* as shown in Fig. 9 it is seen that the force at *5* is greater than the force at *7*, since the spring *8*, *9*, *10* is in its normal position, while the spring *2*, *3'*, 4 is subjected to a greater deflection than it had in its normal position. It is, therefore, evident that if the equal beams *5*, *6*, *7* and the spring *8*, *9*, *10* are released they will assume the position as shown in Fig. 10, in which

position the force at *5′* will equal the force at *7′* and the deflection of the spring *8′*, *9*, *10* will be the same as the deflection of the spring *2*, *3′*, *4′*. Assuming the equalizing system of the two sides of the locomotive to be of the type indicated in Fig. 5 and that we have been considering the system on the near side of the locomotive, we will find that on the near side both of the semi-elliptic spring *2*, *3′*, *4′* and *8′*, *9*, *10* are deflected, due to the elevation of the wheel E, while the springs on the far side of the locomotive are subjected only to the normal deflection of carrying the static load imposed on them by the spring born parts. Therefore, the springs on the near side of the locomotive are carrying more weight than the springs on the far side of the locomotive and the locomotive spring born parts are not in transverse equilibrium. Equilibrium will be restored by the near side of the spring born parts rising vertically upwards until the springs on this side straighten out to their normal deflection as indicated by the dotted positions in Fig. 11. Three of the wheels are then standing in normal position and one wheel is elevated and yet the weight distribution is practically the same as it was with all the wheels in normal position.

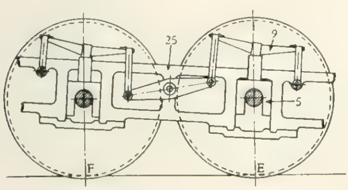


FIG. 12—SHOWING INSTABILITY OF SINGLE POINT OF EQUALIZATION

In the foregoing description the effects of inertia have been disregarded to bring out the elementary principles of equalization and the discussion is, therefore, correct only when the wheel in climbing on to the high spot, occupied sufficient time to allow all the actions noted to take place. As the locomotive speed increases, however, more and more lag will occur in these actions. This is one reason why a high speed locomotive cannot negotiate track that might be operative for a slower speed machine.

SINGLE POINT OF EQUALIZATION DEFINED

It was stated that wheels grouped as shown in Fig. 5 constitute a single point of equalization. A single point of equalization is a system which, irrespective of the number of wheels involved, controls displacement of the spring born parts against rotation about a single axis. For instance, the single point of equalization shown in Fig. 5 controls the rotation of the spring born parts about an axis parallel to the rails but offers no restraint against rotation about an axis in the horizontal plane at right angles

to the rails. This becomes apparent by studying Fig. 12 where the entire spring born parts have tilted about an axis at right angles to the rails until the frame *25* has come in contact with the top of the journal box *5*. There is no tendency for the spring born parts to resume their normal position, and it is evident that the system of equalization shown is inoperative, except for the very slowest speed, because if the wheel *E* were to strike a high spot with the locomotive running at medium or high speed it would deliver a hammer blow upon the rail. This blow would be backed up by the entire weight carried on the wheel *E*, both dead and spring born, since the spring *9* would have no opportunity to work. The equalization shown is then similar in principle to the dumb-bell shown in Figs. 1, 2 and 3.

An operative system of equalization is shown in Figs. 13 and 14. The equalization of the axles *E* and *F* in these figures is identical with that shown in Fig. 5. Each wheel on the additional axle

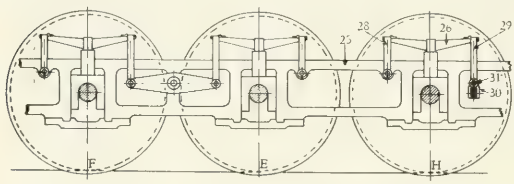


FIG. 13

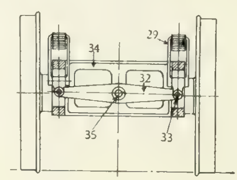


FIG. 14

THREE POINTS OF EQUALIZATION

H is equipped with a semi-elliptic spring *26* resting upon a saddle. One end of each spring is secured directly to the side frame *25* by means of a hanger *28*. The other end is fitted with a hanger *29* whose lower end is connected to a clevis *30* by the pin *31*. This clevis is connected as shown in Fig. 14 to a cross equal beam *32*, this connection being through a pin *33*. The center of the cross equal beam *32* is connected to a locomotive cross tie *34* by a pin *35*. The cross tie *34* is rigidly connected to the locomotive side frames and is, therefore, a part of the spring born weights. The distribution of weight upon the axle *H* is diagrammatically indicated in Figs. 15 and 16.

Assume that the near wheel on the axle *H* is raised by a high spot in the track to the position *H'*, Fig. 15. The deflection of the spring *13*, *14'*, *15* is the same as that of the spring *2*, *3'* *4* in Fig. 9. Figs. 17 and 18 show the positions assumed by the near and far springs and the cross equal beam, the near spring being shown dotted and the far spring being shown dot and dash. In

Fig. 17, due to the deflection of the near and far spring beyond the normal deflection, it is evident that these two springs are bearing more than their share of the spring born weight of the locomotive. The spring born weight will, therefore, be rotated approximately about point *6* and the positions assumed by the various levers and springs are indicated in Figs. 19 and 20.

In this sytem it will be seen that the rotation of the spring born parts is controlled about horizontal axes, both parallel with and at right angles to the rails. It is, therefore, controlled

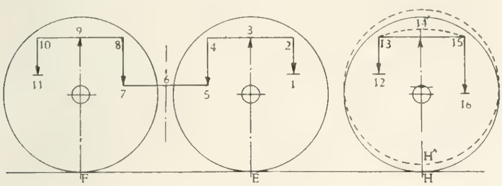


FIG. 15

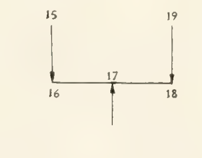


FIG. 16

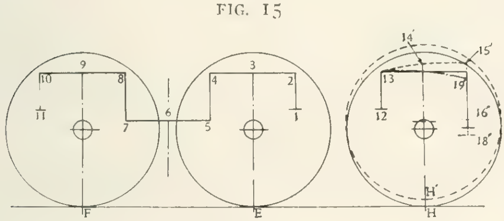


FIG. 17

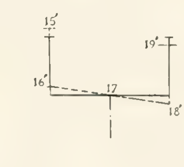


FIG. 18

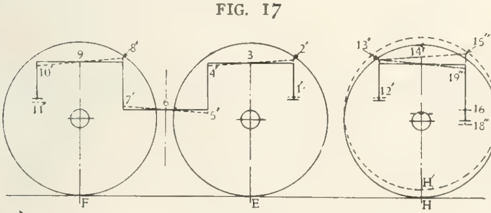


FIG. 19

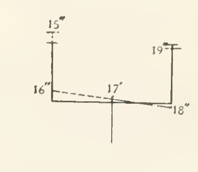


FIG. 20

SHOWING STABILITY OF THREE POINTS OF EQUALIZATION

for all rotations about axes in the horizontal plane. The rails control the rotation of these parts about axes in the vertical plane and therefore the spring born parts are completely under control. The performance of this system of equalization can be examined by precisely similar methods for a vertical displacement of any of the wheels, either up or down, and it will be seen that when the system has found its equilibrium the distribution of the weights upon the various wheels will not be materially changed by variations that exist in track of standard construction.

THE ESSENTIALS OF SUCCESS IN SALESMANSHIP*

T. H. BAILEY WHIPPLE

COMPETITION is so keen, and price and quality of competing products among the leading staples are so rapidly approaching a plane of closely approximate equality, that greater skill is now necessary to the accomplishment of success in salesmanship than at any previous era in the long history of commerce. In considering the question of the adoption of salesmanship as a profession the wisest plan would be to give due consideration to the essentials of success.

The essentials of success in salesmanship are:—

1—A correct mental attitude toward the vocation of salesmanship.

2—A comprehensive knowledge of the products offered for sale and of competitive products.

3—The utilization of such knowledge of your own and competitive products. This involves the art of putting things, the power of commercial analysis, the power of demonstration. Not merely the power of logical argumentation, but the persuasive power that clinches the sale. By strong argument you may carry conviction to the mind of a prospect, but by insufficient tact you may fail to transform this conviction into the willingness to sign the desired order.

4—Industry—This quality should be constant, systematized and directed with intelligence and zeal. Success depends not so much upon the "genius of inspiration" as upon the "genius of perspiration."

5—Confidence—This strong quality is based upon the merits of your proposal, as a whole; the character of your company and its products; the reasonableness of your prices and terms, and consciousness of your worthiness as a salesman. This is "confidence without conceit."

6—Respectfulness—This involves an agreeable disposition, permitting an alignment with your company's policy and successful coöperation, both with associate employees and with your customers who purchase for re-sale, and also fairness to your competitors when it is necessary or advisable to mention them or their products.

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*Abstracted from a recent address by the author on "Salesmanship."

All of these qualities should be coupled with the one imperative requirement, which must always alloy itself with every other element of the art of selling, viz., gentility of bearing and conduct and another equally imperative quality, viz., health.

It will be noted that in these essential elements of success in salesmanship, no mention has been made of the higher characteristics and qualities of Initiative, Intuition, Tact, Diplomacy, Memory, Imagination, Charm of Manner, Judgment, Knowledge of Human Nature. These omissions are due to the belief that success, within the limitations of the average salesman, is due almost wholly to the talent for hard work, together with earnestness and sincerity, associated with kindliness, fair mindedness and patience and also to the writer's belief that the sales problem must, to a very large extent, deal with mediocrity and its refinement. To employ and modify an idea of Lincoln's—God must have loved the mediocre, else he would not have made so many of us. At any rate, mediocrity and its utilization play a prominent part in the economy of commerce and its higher refinement will increase commercial efficiency and will prove the chief measure by which trade supremacy will be achieved and maintained.

From the foregoing it is evident that the salesman can be educated and moulded or, to use a shop expression, can be manufactured from raw material of reasonable suitableness, and the belief of almost universal acceptance to the effect that "the salesman is born, not made," is largely erroneous and unfortunately misleading and discouraging. A "born salesman" with equal training may reach a higher success and a quicker success, and that is all. This "bornness" often entails so many infirmities of genius as to greatly modify its value. In the game of salesmanship, as it is beginning to be played today, "bornness" untrained cannot compete with highly trained mediocrity. This is especially true in the sale of products requiring engineering and technical knowledge.

Successful salesmanship means correct theory put into successful practice. It means the welding of self-reliance to up-to-date co-operative methods; it means the conversion of capacity into ability; it means facing with courage life's conditions as they are, and adapting one's self advantageously to such conditions. It means the proper adjustment of self into the machinery of commerce and human affairs. It means adaptability, resourcefulness, courage, patience, fortitude, quick perception, optimism

and enthusiasm. It means, in its higher sense, skillful and harmonious execution upon the keyboard of human nature. The profession is dignified enough and its highest exactions are universal enough to challenge the admiration, interest and genius of the greatest intellects. One who feels himself above it or who is actuated in its adoption solely by mercenary considerations, had better turn back and devote his time and talents to some other pursuit.

We are built upon certain lines of taste and aptitude and while sheer intellect and perseverance can overcome many of Nature's handicaps, it is best, when choosing a life profession, not to put square pegs into round holes. The man endowed with a superabundance of nervous energy and balancing qualities, will make the most successful salesman, while the man of phlegmatic temperament had better turn his attention to some calling where pronounced personality, energy and magnetism do not count for so much. With the qualified salesman, there is no uncertainty concerning average results within certain time limits, yet the inherent nature of the vocation spells uncertainty as to immediate or specific results. The profession thus incorporates the elements of speculation and sport, which excite interest and are a perpetual stimulus to one who loves the game. This question of the salesman's attitude toward the profession could be indefinitely expanded, but enough has been said to indicate that it is the corner stone in the foundation of the salesmanship structure.

The second essential of success in salesmanship, as mentioned in the foregoing, was a comprehensive knowledge of the products offered for sale and of competitive products. We are now entering the realm of practicality and are moving away from mere theoretical consideration. The teaching of salesmanship theoretically or in the abstract is of relatively small practical value to the student. It is on a par with teaching moral and mental philosophy, psychology, metaphysics, ethics, business etiquette, etc. The most practical way to teach the art of selling is in the field, but even field training would be much more effective if the student entered upon field work with a thorough previous knowledge of the products offered for sale. Sales application of knowledge should follow the acquirement of the broad fundamental principles and distinguishing characteristics of the articles offered for sale.

Too many so-called salesmen get much of their business education in the "University of Hard-Knocks." The profession

would be more respected if the trade had not so often been the victim upon which the ignorant novitiate practiced. It is commercially criminal for any company to provide its salesman with expense money, railroad time tables, catalogues, price books, and practically no other qualifications, except vulgar and brazen nerve and inflict these trade ambassadors upon a long-suffering commercial public. Business men are supposed to be the very sanest of human beings, priding themselves upon their sound judgment and exacting value for every heavy expenditure and yet they delegate their very fortunes, prosperity and reputation to the performance of salesmen more scantily prepared for the trusteeship than is the barber for the practice of his trade. The writer's observation of salesmen in the field, an observation extending over many years, is that the average salesman possesses but a limited knowledge of the products he handles and that his knowledge of the art of selling is even more meagre than his knowledge of the goods offered for sale. Surely not one salesman in twenty utilizes to a high degree his native ability, but is satisfied to operate at from twenty to forty percent of his normal mental capacity.

Years of close observation have convinced the writer that most salesmen proceed upon a haphazard basis, acquiring but little knowledge of their business that cannot be acquired by unconscious absorption and giving even less attention to the refinement of methods of presentation of their knowledge to the prospect. The same indifference applied to any other profession or even trade, would inevitably spell failure. It is no wonder that statistics prove that, of those entering the ranks of salesmanship, only five percent succeed. In the face of severe competition success does not come easy, even with the best of equipment, and it is strange that greater stress is not laid, by both employers and salesmen, upon the necessity of thorough preparation for sales work.

This willingness to be satisfied with the minimum, not trying to do one's work to a finish, not constantly endeavoring to be a 100-point salesman, accounts for the many failures and the low average of success. It is claimed that incompetency costs the city of Chicago one million dollars per day. John Wanamaker says that incompetency costs his company twenty-five thousand dollars per day. The high percentage of inefficiency is not due to lack of capacity, but to indifference, to mental laziness. The average salesman, in the treatment of his profession, vegetates and does but little thinking aside from the mechanical or automatic kind. If

salesmanship were treated as seriously as other professions, the cost of the exploitation of merchandise would be reduced by more than half.

The purpose of any salesman's educational endeavor should be:—

1—To do all within one's power, during business hours and leisure hours, to acquire a thorough knowledge of the theory, characteristics and application of his own and competing products.

2—To continue this study assiduously as long as one is engaged in the sale of apparatus.

3—To daily consider the possibility of improvement in the art of presenting the advantages of one's product to the trade.

4—To daily study better methods of enlisting the attention of the prospective customer.

5—To daily study better methods of maintaining and increasing the satisfaction of users of one's apparatus.

6—To daily consider the question of better methods for increasing the productiveness of one's territory.

Ordinary comprehension of a subject is often mistaken for the power to marshal one's forces and clearly explain the subject to another. Read a section explaining the characteristics of your apparatus and note the readiness with which you understand its meaning. After having done this, pick up your pen and try to reproduce, even in substance, all of what you have read and see how difficult or even impossible it is to do so. "If you want to know a subject, write a book about it." Every salesman should write out his sales talk upon each article of sale, and then revise it often enough to insure the introduction into it of the most logical arrangement of the subject and its most convincing presentation, selecting the very best language that he can command. He should then familiarize himself with his own production and cultivate the most impressive and effective delivery.

Personality is a tremendous factor in salesmanship and it can be cultivated and intensified. Success so often hinges upon this one feature, this question, not of knowledge solely, but of its refinement and skillful presentation, that it is strange that such utility is treated with indifference. Two men of equal mental ability adopt the stage as a profession—each plays Hamlet and each is upon a par with the other respecting the correct comprehension of Shakespeare's master creation. Yet one greatly surpasses the other in the genius of impersonation, in elocutionary

power and refinement of interpretation, and due to this difference alone one is an acknowledged star of great popularity while the other is an actor of ordinary reputation.

The art of expression is a rare accomplishment, but one that any person of education can develop to a high degree. No accomplishment counts for more in successful salesmanship than does the power of terse and lucid expression. While thought precedes expression, yet expression, by a peculiar phase of reverse action, clarifies and strengthens thought. To quote from Edgar A. Russell, the author of "Ethics and Principles of Salesmanship"—"The deeper the knowledge, the broader the culture, the keener the reasoning faculties, the stronger will be the power of expression." "We may lay down the proposition that knowledge lacks potentiality unless it is accompanied by the power of expression." In studying to develop expression we stimulate imagination, strengthen logic and attain greater confidence and poise, thus creating and assembling all those faculties, the combined exercise of which carries conviction.

The best self-training the writer ever secured was in writing circular letters, editing catalogues and writing out his best arguments setting forth the advantages of his company's products over competing products, and in preparing convention papers.

We can afford to systematically and continually study to increase our knowledge and to refine our art of conveying it to others. It has been said that Balzac, one of the most prolific writers and a genius ranking with Shakespeare and Goethe, has spent as much as a week upon a single page of his writings; Noah Webster spent thirty-six years of continuous work producing his dictionary; Cyrus Field crossed the ocean fifty times to lay a single cable; Turner made 30 000 drawings before he achieved his "Slave Ship" and immortality; Gibbon worked twenty-six years on his "Decline and Fall of the Roman Empire;" Stephenson put in seventeen consecutive years perfecting his locomotive; Napoleon Bonaparte worked nineteen hours per day and Thos. A. Edison eighteen hours per day for many years of their lives.

No matter how great your genius, high success means hard digging and everlasting digging. Strive to "do it better"—better than your competitor; better than your associates; better than your own past records, and your reasonable success is assured in advance.

NOTES ON DRAFTING ROOM LIGHTING

C. E. CLEWELL

[This article includes experiments conducted for determining the conditions as to intensity and the arrangement and number of lamps required to furnish suitable illumination for a certain drafting room.]

FEW classes of work call for more active and constant use of the eye than that of the draftsman. The necessity for continual distinction of fine lines and details and the use of finely divided measuring scales and delicate instruments warrants a system of illumination free from all feaures likely to to produce eye fatigue and eye strain, and capable of promoting ease and comfort in such work. The problem is not altogether one of providing light of high intensity. Too much light may be as harmful as insufficient light.

The general requirements for such lighting are:—

1—Good and sufficient light for each person.

2—Uniform distribution of light provided by lamps in such numbers and so arranged as to furnish an illumination which is satisfactory without regard to the arrangement of drawing tables.

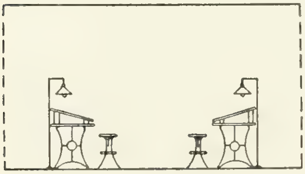

FIG. 1—COMMON FORM OF DRAFTING ROOM LIGHTING

3—An arrangement of lamps that will avoid glare and subsequent eye strain.

4—A system which will furnish illumination on the drawing boards with a minimum of shadow effect when using instruments and ruling devices.

5—An intensity of illumination which will permit the discernment with ease of fine lines and details, and which will be sufficiently penetrating for tracing work.

Numerous methods have been used for the lighting of drafting rooms, some of which possess several of the features outlined above, but seldom fulfilling all the requirements. For example, one method of drafting room illumination is that in which one or two light units, provided with reflectors are, placed close to the work, This system, shown in Fig. 1, casts an intense light on the paper which is not, however, uniform and it is necessary to change the units when the position of desks is shifted, often making wiring changes necessary in such cases. A system of this kind produces a glare from the surface of certain kinds of paper and subsequent eye fatigue. It should be further noted that the resulting shadows

are excessive and this requires a continual shifting of the work or lamps and a consequent delay and annoyance.

In an investigation of drafting room lighting, tests were made in a typical drafting room with bays 16 by 20 feet and a ceiling height of 11 feet 6 inches. A sectional view and floor plan of such a bay is shown in Fig. 2. This typical drafting room contained an average of four tables per bay and could accomodate four persons per bay. The room was originally equipped with large light units spaced on an average of from eight to ten feet apart and mounted ten feet above the floor or about five feet six inches above the drawing boards. The arrangement is equivalent to about three lamps per bay, or 25 watts per square foot. The arrangement of the lamps in a typical bay is shown in Fig. 2. The complaints from the use of this lighting scheme were three fold:—

1—The illumination was not uniform, the intensity on some desks being higher than on others.

2—The low mounting height of the lamps together with the large size of the units required to furnish sufficient light caused those in certain positions to suffer from excessive eye strain, both from the glare of the light source and from the reflected light on the papers.

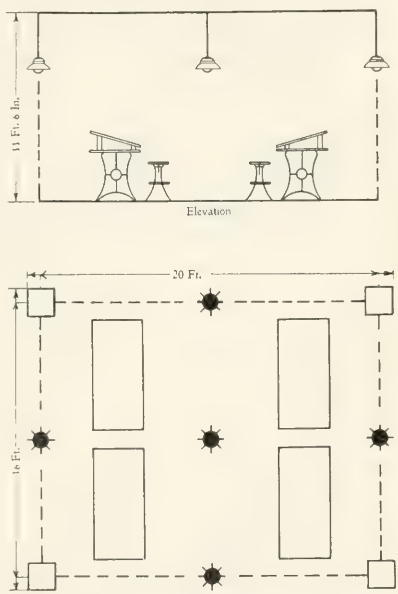

FIG. 2—TYPICAL BAY OF A DRAFTING ROOM LIGHTED BY LARGE LAMPS

3—Shadows from the small number of large units were dense and required a constant shifting of the ruling devices so as to receive the light on the work at the proper place.

The problem was to provide illumination possessing all the requirements as outlined above, and with features of such excellence as to be satisfactory in all respects for a class of work which rightfully calls for superior lighting facilities. The study

of the requirements will show that uniformity, the absence of shadows and the reduction of glare are the conditions most difficult to obtain. Several methods were given thorough trial before the final scheme was chosen.

The first step was the installation of nine units somewhat smaller than those originally used, arranged as indicated in Fig. 3. Certain draftsmen were set to work in this trial bay. From the start the following items were observed: The intensity was excellent, the light uniform, and the glare not appreciable. It soon became apparent, however, that the shadows cast by the large number of units were an objectionable feature. In drawing circles and in the use of the divider generally, some nine shadows standing out in all directions from the instrument and apparently rotating when a circle was described were confusing and annoying. This feature naturally gave rise to considerable complaint. This led to the suggeston that the shadows might be diminished by the use of more units for a given floor space arranged in groups. As a second experiment twelve units were arranged as shown in Fig. 4, the system being made up of four 100-watt and eight 40-watt tungsten lamps per bay. Draftsmen were then placed in this bay so as to work under the light for some days. The same trouble was experienced with shadows in excessive numbers as was the case in the first trial, the effect being even more noticeable due to there being twelve lamps per bay instead of nine as before. The feature of uniformity was further inferior in this scheme, since the clusters may be considered as one light source so far as independence of desk locations is concerned, and the superiority of nine versus four light sources or groups per bay was demonstrated.

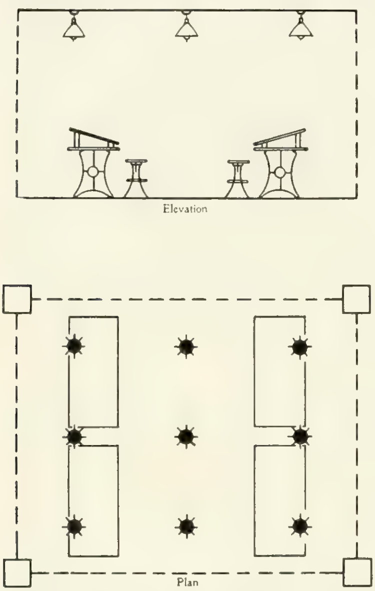

FIG. 3—TYPICAL BAY LIGHTED BY NINE LAMPS

Other arrangements which were given trial were as follows:—One bay was furnished as an extreme case with 21 light units

scattered over the ceiling. Here the shadow effect was perhaps somewhat offset by an excessive intensity, but the use of lamps in such numbers would be prohibitive in point of economy, and even if this were not the case it is questionable whether such large numbers of lamps would be admissable from the standopint of good taste.

An arrangement of four 250-watt tungsten lamps per bay, equipped with broadly distributing reflectors, was tried. This arrangement, while possessing some good points, made use of units entirely too large for the ceiling height. Calculations were made to determine the minimizing of shadow effect in large rooms by the use of broadly distributing reflectors rather than those of a more concentrating type. This involves the building up of intensity at a given point by the light furnished by many distant light sources rather than being entirely dependent upon the light from one overhead unit. A man leaning over his work will cast a deep shadow, cutting off nearly all of the light if provided by one unit overhead and little or none from distant units; whereas if the units are provided with broadly distributing reflectors such shadows will be far less noticeable.

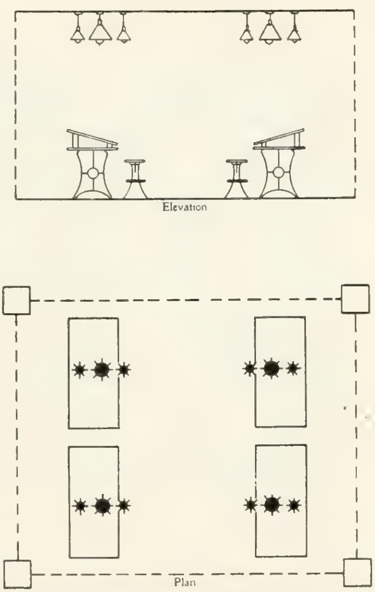

FIG. 4—TYPICAL BAY LIGHTED BY 4-100 WATT AND 8-40 WATT LAMPS

The plan finally adopted consisted of the use of sixteen 40-watt tungsten lamps per bay arranged in clusters of four each, by mounting the units on fixtures so constructed as to make use of the lamps in an inverted position as shown in Fig. 5. The primary thought in this scheme was the attainment of a light free from the shadows found in previous trials. Various types of reflectors and fixtures of different shapes as well as effective mounting heights of the lamps above the floor were successively tried. With the ceiling freshly painted a yellow tint so as to present a coefficient of reflection of about 0.7, the following items

were observed:—Opaque reflectors which furnished no transmitted light, all of the light coming from ceiling reflection, while providing uniform shadowless illumination did not furnish a sufficient intensity for the work in question. The reflectors seemed to give the best results when mounted in a vertical position pointing upwards, rather than when mounted in an angular position. Reflectors of a softly diffusing quality of glass and which furnished a considerable amount of transmitted light to the work, seemed to fulfill all the requirements as outlined above. Each draftsman, irrespective of desk or table location, received a good and sufficient light. This light was uniform and was made soft and free from glare by a glass reflector providing excellent diffusion and a soft yellow tint. The shadows were eliminated and with the use of the proper size of lamps an intensity of suitable value was provided throughout the room. This system has been in service long enough to show that, within the limitations of ceiling height and types of units and reflectors available, a very satisfactory result has been obtained.

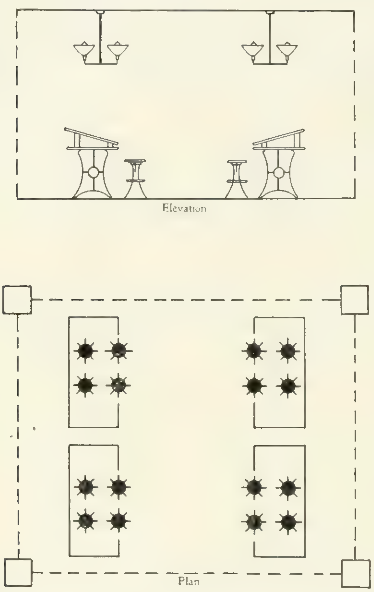

FIG. 5—ARRANGEMENT FINALLY ADAPTED CONSISTING OF 16-40 WATT LAMPS

It is of interest to note that the wattage per bay with this last scheme was practically the same as that found in the original installation. Hence the superior results were obtained by no extravagant installation of larger wattage, but by a carefully arranged plan of the equivalent wattage in another form. The approximate installation expense of the system originally found in use was slightly higher than the new one and the operating expense was sensibly the same as that of the system finally chosen.

It should be stated that the final arrangement of this lighting system was the outcome of experiment rather than predetermination. Much careful study was given to the problem, as it had been

anticipated that nine, or at least twelve units per bay, used so as to furnish direct light to the work, would be satisfactory. Draftsmen without exception, after working for a time under one trial installation after another, favored the final system as furnishing the best illumination of any that had been tried.

In such a lighting installation as that just described it is likely that different intensities of the artificial light may be needed at different portions of the day and evening. At first thought the usual conclusion is that more artificial light is required at night than on cloudy days. Experience shows the reverse. During the day the eye is subjected to a stimulus from daylight intensities which

FIG. 6—VIEW OF A DRAFTING ROOM LIGHTED WITH INVERTED TUNGSTEN LAMPS FITTED WITH DIFFUSING REFLECTORS

are ordinarily many times greater than the intensities of artificial light commonly used. In the daytime this causes the pupil of the eye to be in a contracted state so that it requires a greater intensity on the object than is necessary when the eye is relaxed as at night. Thus on a cloudy day, when the daylight is insufficient, a greater intensity of the added artificial light is necessary to produce a satisfactory illumination on the working surface than at night. If the lighting system has been designed for an intensity suitable when used in conjuction with some daylight, it is quite possible that the intensity will be too high for comfort at night. Some way of changing the intensity of the light without destroying its

uniform distribution is therefore desirable. If lamps be turned out here and there at random for the purpose of reducing the intensity to the proper value at night, the uniformity of the light is apt to be destroyed.

One method of varying the intensity without destroying the uniformity of the light consists in installing the lamps in groups, and turning out a part of the lamps in each group. This affords different intensities without disturbing the uniformity of the light. Often, however, the lamps are not in groups.

The tungsten lamp possesses one feature which can be used to advantage in accomplishing this end, whatever the number and arrangement of lamps. From the normal voltage of the lamp to about fifteen or twenty percent below normal, the light of the tungsten lamp maintains its characteristic white color. The voltage on such a lighting system may be reduced by means of a transformer arranged with a number of secondary taps to give voltages below normal, thus permitting a change from normal intensity to lower values without noticeably affecting the white quality of the light. This scheme has been used and furnishes a convenient method of varying the light intensity without destroying the uniformity of distribution.

ELECTRICALLY OPERATED TURN TABLES

E. C. WAYNE

ECONOMY of time and of operative cost are the two most important considerations in the operation of railway turn tables. The relative importance of these two features depends on the amount of traffic to be handled. At a very busy terminal yard the saving of time becomes the first consideration, and any device that will lessen the time required to handle engines and cars is welcomed. At the same time the careful and efficient management of modern railway systems requires that no unnecessary expense be incurred either in the first cost of apparatus or in the cost of its operation.

Turn tables are commonly employed to connect the tracks in

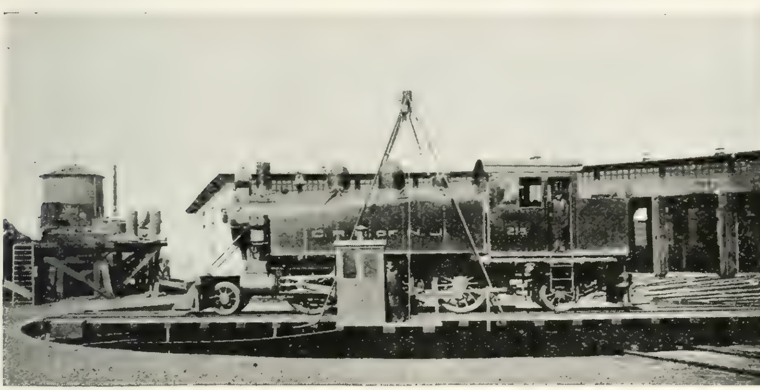

FIG. 1—VIEW OF A TYPICAL TURN TABLE AND ROUND HOUSE

a railroad round house which, radiating from a common center, are used for the storage of engines. They vary in length from 50 to 100 feet, most of those installed at the present time being 70 to 80 feet long and weighing from 30 to 40 tons. The rotating structure is built up of steel girders, suitably braced, and is rotated about a pivot at the center, the ends being supported by trucks which run on a single circular track, placed in the turn table pit. On the top of the table are rails which register with one set of tracks after another, as the table is rotated. A typical turn table and round house are shown in Fig. 1.

Many of the turn tables now in use are operated by hand, although the results are far from satisfactory. The process is

slow and unless the engine is perfectly balanced it takes the united effort of several men to start the table and keep it in motion. Then, too, the tendency for years has been toward the use of heavier engines and today it is by no means unusual to find an engine and tender weighing above 200 tons. The increasing frequency with which turn tables are used, together with the greater weight of the rolling stock, have compelled many roads to install power drive. Engines operated by air, steam, gas or gasoline have been used for this purpose and have resulted in a saving both of time and operating expenses. However, the increasing use of electricity by the railroads is causing these devices to be replaced by electric motors, and the results in service have shown a still further saving in time and expense. This is largely due to the higher efficiency of the electric motor, coupled with its greater reliability and simplicity of control. Then again it is quite often the case that the same type of motor can be used to drive the turn table that has been applied to some other piece of apparatus around the yards. This, naturally, effects a saving in repair parts.

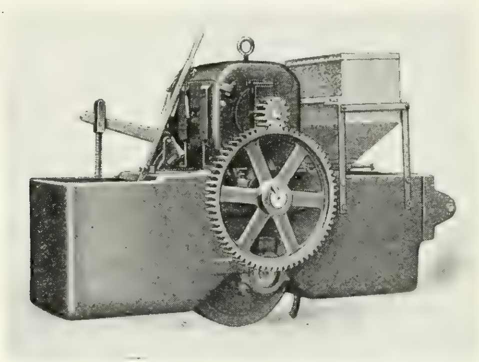

FIG. 2—SMALL TRACTOR EQUIPPED WITH DIRECT-CURRENT MOTOR

Average operating conditions are shown in the following account, which applies to a railway turn table where an electric tractor superseded hand operation. The total cost of the electrical equipment, including installation, was approximately $1 500.00.

ANNUAL EXPENSE OF HAND OPERATION

Two men 24 hr. per day, at 15c per hour		$2 628.00

ANNUAL EXPENSE OF MOTOR OPERATION

One man 24 hr. per day, at 15c per hour	$1 314.00	
Current, average $8.00 per month	96.00	
		$1 410.00
Annual reduction effected by the use of electricity		$1 218.00

If to the operating expense be added a charge of 12 percent of the cost of the electric installation, or $180.00, for interest

and depreciation, the balance in favor of motor operation is still \$1 038.00. In addition, the saving in time and the increased amount of traffic that can be handled in a given period, while difficult to reduce to actual figures, will be of greater importance in a crowded round house than the saving in operating expense.

CONSTRUCTION

The motor is ordinarily applied to a heavy rectangular frame constructed of cast iron or steel and termed a "tractor". A single steel tired, double flanged driving wheel mounted in the tractor frame runs on the same rail as the turn table truck. Connection between motor and traction wheel is effected by means of double reduction gearing. The tractor is preferably attached to the table by a hinge joint connection which allows some flexibility of connection and minimizes the jar to the tractor when the engine runs on or off the table. In some installations the motor has been mounted directly on the table, but this arrangement is not as satisfactory on account of the jolting to which the motor is subjected.

FIG. 3—LARGE TRACTOR WITH CAB

Occasionally a separate rail is installed on which the tractor can operate, the object being to insure a lower rolling friction for the table. In starting it frequently becomes necessary to use sand under the tractor wheel and it is evident that when both tractor wheel and turn table truck run on the same rail, the rolling friction of the latter is greater than it would be with the rail clean. However, this additional refinement is not usually considered essential.

EQUIPMENT

The turn table equipment consists, in addition to the motor, of a brake and sander, rail locking device, controller, resistor,

circuit breaker and current collector. The controller and circuit breaker, together with levers for operating the brake, sander and locking device are contained in a cab located either in the center of the table or mounted on the tractor itself. The former arrangement is usually employed with the smaller sizes of tractors as shown in Fig. 2 and the latter, shown in Fig. 3, where longer and heavier tables have to be turned. It will be noted that in the first case the motor is mounted on top of the tractor and in the second inside of the frame.

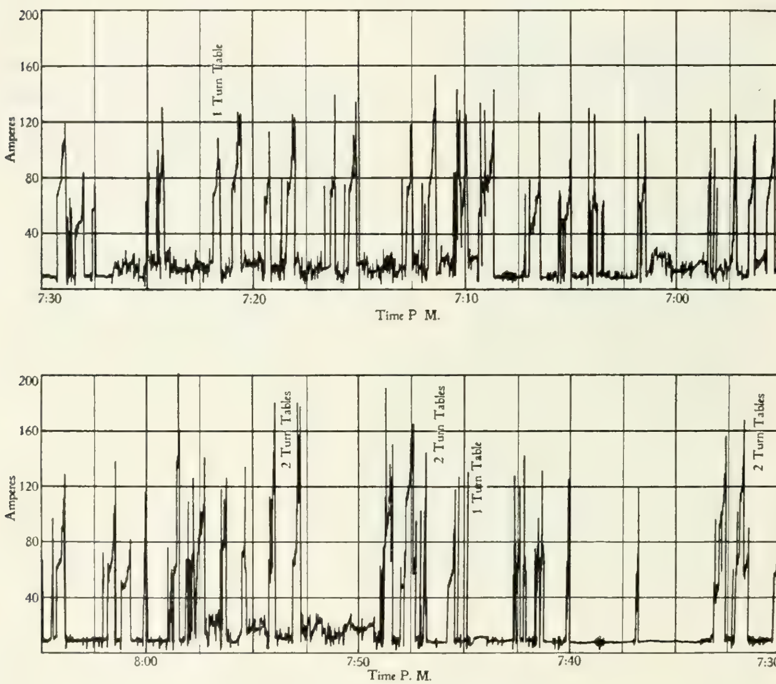

FIG. 4—GRAPHIC METER RECORD IN A CIRCUIT LEADING TO THREE MOTORS OPERATED TURN TABLES

There are two important points to be considered in the location of the cab, namely, the convenience and the comfort of the operator. It should be so situated that the jolts to which he is subjected will be reduced to a minimum and yet be near enough to the radiating tracks to enable him to make accurate alignment promptly. This is especially true where a large number of engines are to be turned, as otherwise time will be lost in lining up the tracks, thus defeating to a certain extent the purpose for which

electric drive was installed. Again the operator cannot stand the continual vibrations to which the end of the table is subjected for any length of time. The center of the table is naturally the point where the least vibration occurs, and it is for this reason that in the smaller installations the cab is located there. However, where larger engines have to be handled this means longer tables, and in this case were the operator at the center he would have difficulty in track alignment. If it were only necessary to consider this point, the logical place for the cab would be at the end of the table, but it is here that the vibration is greatest and the shock received by the operator as each engine came on or left the table would be very severe. The alternative is to mount the cab on the tractor itself directly over the driving wheel, the flexible connection between tractor and table relieving the operator from the jolting. This is generally done, as experience has shown that the freedom from shock more than offsets the slight advantage which would be gained by having the operator located directly at the point where the tracks come together.

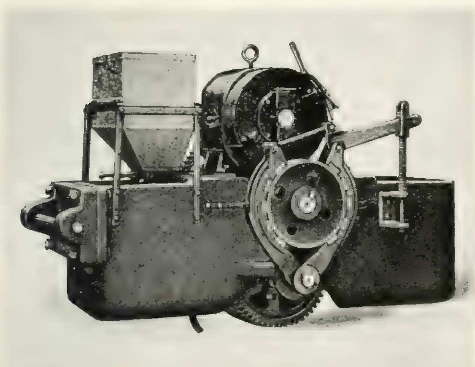

FIG. 5—VIEW OF TRACTOR SHOWING BRAKE

The Motor—From the above description it is apparent that the tractor is in reality a single wheel locomotive and consequently must be equipped with a motor suitable for frequent starting and capable of withstanding large momentary overloads. Where direct current is available, these conditions are well met by the series wound, railway type of motor. In the case of alternating-current installations, polyphase slip ring induction motors are best adapted to this work. Experience has shown that anything less than 15 hp is not to be recommended as a general rule, although there are some installations where smaller machines are apparently giving satisfactory service. Motors from 10 to 15 hp are, as a usual thing, applied to tractors of the type shown in Fig. 2. If the conditions call for a capacity of 20 to 30 hp, the tractor is built in accordance with the design shown in Fig. 3.

The size of motor is, of course, dependent upon the weight and rolling friction of the table with load, the diameter of track, and the time in which it is desired to make one complete revolution. It is usually possible to obtain prints of the turn table and wheel load diagrams of the heaviest engines which will have to be turned. From these can be figured the pull which the tractor must exert in order to operate the table under the worst possible conditions, with the engine and tender unbalanced. The maximum draw-bar pull considered in connection with the speed, determines the capacity of motor which should be selected.

A good idea of the power requirements of heavy passenger service at an important terminal can be obtained from the diagram, Fig. 4, which is a record from a graphic recording meter placed

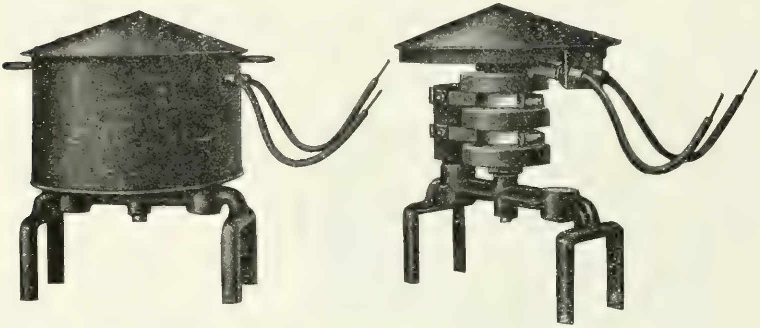

FIG. 6—GENERAL AND DETAIL VIEW OF OVERHEAD COLLECTING DEVICE

in the main feeder circuit of three 23 hp, 220 volt, direct-current series motors, each motor operating a 70 foot turn table. The record was taken at the evening rush hour when often two and sometimes three tables were in use simultaneously. It is evident from the diagram that a loaded table of this size requires about 120 amperes at 220 volts, or from 30 to 35 hp at the moment of starting. This peak falls instantly, however, and only about one-half this amount of power is required to keep the table in motion.

The Controller is of a design which provides for operating at several different speeds forward and reverse and is arranged to obtain very slow speed just before stopping, in order to facilitate lining up the track. To further assist in this a hand operated shoe brake is provided, the wheel being mounted on the end of the counter shaft outside the tractor frame. Powerful leverage is thus provided and the heavily loaded table can be stopped within

a short space and with the required accuracy. Fig. 5 gives a good idea of the details of this mechanism.

Current-collector—For supplying power to the motor the conductors may be brought up through the turn table center pin and connected to slip rings from which the current is transmitted through brushes to the motor leads. In the case of a new turn table this is undoubtedly the best arrangement, but it usually involves considerable expense where an old table is to be adapted for motor drive. In the latter case wires are sometimes run around the turn table pit and the current collected by trolleys. This is, of course, more or less of a make-shift. A much better scheme is to bring the wires overhead to a collector as shown in Fig. 1. The collector is mounted on a framework erected at the center of the table, guy wires preventing the rotation of the stationary part. By furnishing the correct number of rings, the collector is suitable for direct current or alternating current, either two-phase or three-phase. Detail views of this type of collector are shown in Fig. 6.

CONCLUSION

Briefly stated, the advantages resulting from the use of electric tractors are;—great saving of time with consequent promptness of service; low cost of installation, operation and maintenance; ease of power transmission; absence of all energy loss while motors are idle; simplicity and accuracy of control, and reliability and high efficiency of operation.

WINDING OF DYNAMO-ELECTRIC MACHINES—VII

LARGE ALTERNATING-CURRENT MACHINES

PROBABLY more different kinds and varieties of windings have been and are used in conjunction with large alternating-current motors and generators than with any other type of machines. It is not the intention of this article to cover all these various types in detail, but rather to discuss the processes of winding the more representative types in such a manner that the method of procedure with any special winding will be readily understood.

Engine driven alternators of large size, while in common use, are not being installed in new stations to any extent, owing to the increasing use of turbo-generators. Large water wheel generators are, however, being installed in increasing numbers. Large synchronous motors, of comparatively high speed, are used in motor-generator sets and frequency changers. They are suitable for industrial purposes only where operation at constant speed is required, and starting is infrequent and always without load. Their use is especially desirable when the power-factor of the line is low and correction is desirable. Motors of large size for industrial work are usually of the wound secondary induction type. Such motors are being extensively used by steel mills and other users of large power. They are of very rugged construction with large overload capacity, and are generally wound for slow speeds, and such characteristics as will make them suitable for operation in conjunction with a fly-wheel.

The winding processes on the primary are essentially similar for both synchronous and induction machines. The windings described in the present article can, by a suitable design, be applied to either type in connection with a suitable field winding.

THE CORE

The methods of core assembly of the stator of a large alternating-current machine are very similar to those of a large direct-current armature or a large induction motor secondary. The laminations, vent plates, finger plates, etc., are punched or cast in sectors, with a dove-tail joint to the stator or spider cross ribs. The core is compressed by means of one or more jack screws, and retained by end plates. These may be cast in a solid piece and held

by ring keys, or may be in the form of sectors which are bolted in position. Fig. 104 shows a stator of the former type with the end ring, and part of the first row of punchings in place.

The teeth for an open slot core are lined up with a steel straightening bar which forces any projecting punchings back even with the teeth. If necessary they may be further smoothed up with a file. The teeth for a partly closed slot core are lined up at the top by driving a straightening bar through the opening of the slot. Evenness of the sides and bottom of the slots is secured by filing. The dovetail joints which hold the laminations to the core fit tightly enough, however, to secure good alignment of the punchings, so that ordinarily only enough filing is required to produce a smooth finish.

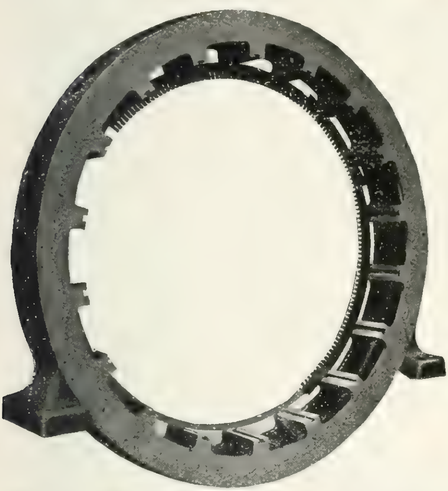

FIG. 104—STATOR FOR ENGINE TYPE GENERATOR, WITH CORE PARTLY ASSEMBLED

THE COILS.

Closed Slots.—In the design of induction motors, the partially closed slot offers the decided advantage that less exciting current is required. This means improved power-factor, greater efficiency and increased output for a given sized machine. In addition the high frequency iron losses caused by the difference in the flux densities over the teeth and the slots are greatly diminished, with the smaller slot opening. All these advantages are greatest in the smaller machines which have a very narrow air-gap, and are diminished with the longer gaps used with the larger machines. On synchronous machines, which usually have comparatively large air-gaps, the open slots are used almost exclusively.

The partly closed slot requires a form of coil which can be either threaded in through the slot opening, or inserted from the end. As it is ordinarily impracticable to insulate the slots for the voltages commonly used on the larger machines by the methods

used for threaded in coils, it becomes necessary either to insulate each strand for the full line voltage, or to use some form of winding in which the complete coil can be insulated from ground and impregnated and then inserted into the slot from the end.

The former method is used where strap diamond coils of a limited number of turns are to be used, and the voltages are moderate. A standard application of this method which is very extensively used on large induction motors consists of a four coil per slot winding. Two strap diamond coils for each slot are completely insulated and impregnated. The width and depth of the insulated coil are each equal to half the width and depth of the slot. The width of the opening at the top is one-half the width of the slot, and the winding process is the same as for an open slot winding except that there are twice as many coils for the number of slots as in an ordinary winding.

FIG. 105—TWO-PHASE CONCENTRIC WINDING
Showing method of testing for short-circuited coils.

Where a number of turns per slot are required with a partly closed slot a concentric shoved through coil, of the type shown in Figs. 105 and 106, is used. This may have as many turns as desired. The coils are formed from double cotton covered wire, round in the smaller sizes and square in the larger. The wires are cut off in lengths equal to the total length of the coil plus enough to allow for joints, and bound together in a long straight bar, having the correct cross-section for the coil. This bar is clamped by the middle in a forming machine, and the ends are bent over suitable wooden forms to give the correct shape to the finished end of the

coil. The two free ends are left straight, so that they may be shoved through the slots.

Open Slots—Although the closed slot has some advantages, as pointed out, in the case of induction motors, the form of winding necessary for more than four or at most six turns per slot, is complicated and expensive to wind. The coils for an open slot winding, on the other hand, are easy and cheap to form, to insulate and to install. A diamond winding can be readily chorded, and thus a standard frame and core can be used for different windings. And in addition, a coil which can be completely insulated and impregnated before insertion in the slots is more reliable. The open slot windings are used exclusively, therefore, for generators and synchronous motors, and for the largest sizes of induction motors.

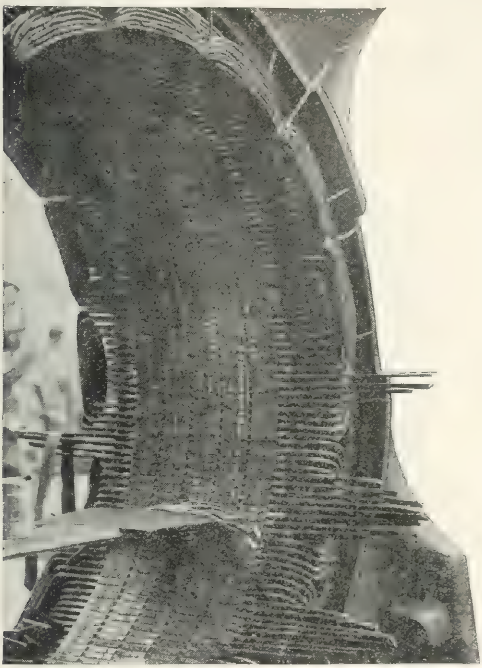

FIG. 106—THREE-PHASE CONCENTRIC WINDING, PARTLY CONNECTED

Both concentric and diamond windings can be used with open slots. Either type of coil is formed at both ends, and completely insulated and impregnated before assembly in the core. The concentric winding takes up less end room where the throw of the coils is great. All the coils in a group are of different size and shape, however, and the adjacent groups must be of different length. On account of the number of different coils used, repairs are difficult to make and a larger supply of extra coils must be kept in stock. For this reason the diamond winding is quite generally preferred. A diamond coil is of a simple form, easy to build and insulate, and one form of coil is used throughout. Repair parts can thus be reduced to a mini-

mum. A typical diamond winding, showing the simplicity of coil formation, is illustrated in Fig. 107. This type of winding may be very open at the ends, allowing a free circulation of air between the coils.

Either the wave or lap form of diamond winding may be used. The end connections, by which the coil ends are connected into groups and the groups into phases, are very much more simple with the wave winding. This form of winding is, therefore, used whenever applicable. The voltage between adjacent coil ends is much greater, but as the coil must be insulated for full line voltage under any conditions, this does not make any particular difference. Where more than one turn per coil is required, however, or where a series-parallel combination is necessary, the wave winding is more cumbersome than the lap winding. It is accordingly used only with a one turn per slot coil, where all the groups in a phase are connected in series. The lap winding is thus much more common as most high voltage machines require more than one turn per slot. The coils may be wound from round or square wire or copper strap, depending on the number of turns and the size of the conductor.

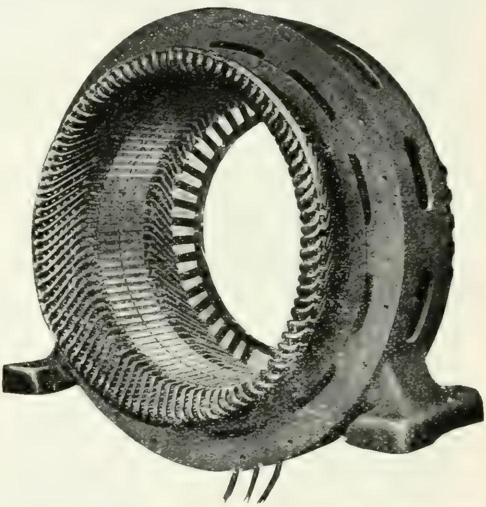

FIG. 107—100 KW DIAMOND WOUND GENERATOR

INSULATION

The insulation to ground is practically the same for a given voltage for all the coils mentioned. The wire in wire wound coils is cotton covered, and no other insulation is used between turns. When coils are made up of two or more layers of conductors, however, the layers are separated by drilling, cotton tape or treated paper, according to the type of coil. Strap conductors may be insulated between turns with overlapping cotton or mica tape. In most cases, however, the tape is used over the ends

of the coils only, the straight parts being insulated by interweaving an insulating cell of cement paper and mica between them. Where several straps are connected in parallel for greater conductivity, they are ordinarily enameled, cotton covered or taped to prevent eddy current loss.

The several turns, whether connected in parallel or series, are bound together with non-overlapping cotton tape and impregnated before being insulated from ground. While drying, the straight parts are clamped in a press so that they will dry perfectly straight and without any interstices between the turns. The hardened impregnating gums bind the dried coil into a compact unit.

The insulation to ground may consist of treated taping over the whole coil, with a protective covering of cotton tape. This material is quite widely used on the smaller machines, and for comparatively low voltages. For larger machines, however, and for high voltages, the customary insulation consists of a wrapper of cement paper and mica on the straight parts and treated tape or mica tape on the ends, with a protective layer of untreated cotton tape or mica tape on the whole coil, overlapping on the ends and non-overlapping on the straight parts. The entire coil is then dipped twice in an insulating varnish, and dried thoroughly in an oven after each dipping. The requisite insulation for the high voltage machines is secured by extra turns of the cement paper and mica wrapper. Not over three and one-half turns is ordinarily used, however, on account of the difficulty of properly impregnating such a coil. Where this does not give sufficient insulation, two or more separate wrappers are used, the coil being twice dipped in varnish and dried after the application of each wrapper.

INSERTING THE COILS

Shoved Through Concentric Coils—This type of winding may be divided into two classes, depending on whether the ends are bent down at one end or bent down at both ends. The winding processes are practically similar for both.

Coils bent down at one end are used on both two-phase and three-phase machines, the two windings being practically identical with the exception of the end connectors. In a two-phase machine the alternate groups are of the same phase, *i. e.*, all the coils in each bank of coil ends belong to the same phase.

In a three-phase machine, with a winding of this type, every

third group belongs to the same phase, and the groups of each phase alternate from one bank to the other. It should be noted in this case that the groups of the same phase do not lie adjacent to one another, but are separated by a distance equal to the pole pitch and that there are only three groups of coils per pair of poles. Where the groups of each phase have one side adjacent to another group of the same phase, under the same pole, with six groups of coils per pair of poles, it is necessary to have three banks, to allow the end connections to cross one another. In this case the coils of two of the banks must be bent down on both ends. The ends of the third bank are, therefore, bent down also, to secure uniformity of the windings.

Considerable care is required in inserting coils of the shoved-through type into the slots. The slots are first cleaned from all foreign matter, iron filings, etc. The coils are rubbed with paraffine, and the slots are lined with paraffined fish paper, cut and bent to an exact fit. The coil is thus made to slip easily into position, and at the same time is protected from damage by sharp edges of the iron. A tight driving fit is absolutely essential with this type of winding. If, on trial, the fit is too loose, strips of treated fullerboard or wood are placed in the slot, or taped to the coils.

The smallest coil in each group is placed in the slots first. It is worked into the slots, both sides at once, until its formed end comes within a short distance of the iron, wooden distance blocks of appropriate dimensions being used to secure uniformity. The other coils are then inserted in order. All the coils of one bank are inserted before the other bank is started. Where a two-bank winding is used, and the coils are bent down at one end only, it is necessary to insert the coils of the different banks from opposite sides of the core. By this method the winder forms only the straight end of the coils, and his work is very much simplified. When a three bank winding is used, however, the winder must bend down the ends of all the coils as he connects them, and in this case it is easier to insert all the coils from one end. After all the coils are in place a fiber retaining wedge is driven in over the top of each coil to hold it tightly in place, the fit being as close as possible without damaging the coil or spreading the lamination at the ventilating slots.

In forming the ends of the coils of both straight and bent down type, wooden blocks are used over which to bend and shape the conductors. The inner layer is connected first, the scheme of con-

nections shown in Fig. 108 giving the best results. The connector consists of a copper sleeve, which is soldered over the ends, the joints being staggered, so that the coil ends will not be unnecessarily bulky. While making the joint it is advisable to protect adjacent conductors from the heat and solder by placing a layer of cloth or mica between them. The finished joint is smoothed off with a file or with emery cloth, and is then insulated with treated cloth and friction tape.

Each coil, during assembly, is bent to correspond with the curve of the stator, as shown in Fig. 106, so that no part of the finished coil will extend above the bore. A piece of insulating material, usually treated fullerboard, is placed between the respective layers, which are bound together with treated cloth and cotton tape, which serves both as insulation from ground and as mechanical protection for the coils.

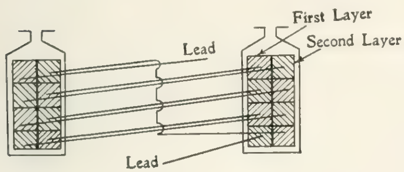

FIG. 108—DIAGRAM OF CONNECTIONS, CONCENTRIC COIL

In the process of connecting, care must be exercised that the ends of the same conductor are not joined together, thus producing a short-circuited turn. This can be prevented by testing out with a lamp. As a precautionary measure, however, after the coils have been all connected, each one is tested out with a testing transformer as shown in Fig. 105. This device is placed over one side of a coil and a thin piece of sheet steel over the other. If there is a closed circuit any place in the coil, a heavy current will flow, and the steel feeler will be strongly attracted to the iron of the core.

Bar and Connector Type—This type of winding consists of solid copper bars which are completely insulated and shoved through the slots. One or two bars may be used per slot. Within an inch or so of the end, the bar is uninsulated and the bare ends are tinned. End connections of diamond or involute form, insulated and provided with tinned ends, are used to complete the coil. In order to facilitate the operation of soldering, the ends of the connectors are slotted or drilled as shown in Fig. 109, as without these openings

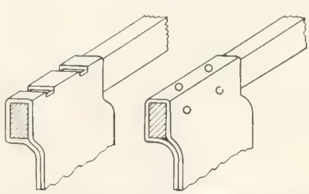

FIG. 109—STUBS FOR BAR AND END CONNECTOR WINDING

it is difficult to force the solder into the center of the joint.

On a two-bar per slot winding, it is necessary that the bar next to the rotor be shorter so that the joints at both ends of the connector will be accessible to a soldering iron. In this case, sufficient filling must be placed between the two bars in the slot to allow the end connector to slip over the top bar with sufficient clearance for taping. In case there is not sufficient room in the slot to allow of this filing, the top bars are cut away, as shown in Fig. 110. The connector is shaped, as shown in Fig. 109, so as to allow it to slip between the lower bars and over the ends of the upper ones. All connectors are soldered in place and the joints are taped.

With this type of winding repairs are very easily made, as any bar can be removed without disturbing the bars in any other slot. It is not adaptable to high voltages, however, on account of the limited number of possible turns. Furthermore, the end connections are very difficult to brace adequately.

DIAMOND COILS.

On large machines the split frame construction is necessitated. Hence, after the machine is completed and tested, the windings must be removed at two points, in order to allow the frame to be disconnected for shipping. Some form of winding must therefore be used that can readily be disconnected and reconnected on arrival at its destination. This condition can be most readily met by the open slot diamond coil. The diamond winding is by far the easiest to put in place, to remove when necessary without damage to the coil, to connect into groups and phases, to brace at the ends, etc. It is therefore coming into almost exclusive use on large or high voltage machines and for all types which have been fairly well standardized.

The assembly of wave and lap windings is practically the same, and the processes on the larger machines are similar to those employed on the smaller ones. The slots are cleaned and lined with fish paper protective cells. The coils are inserted one after the other in order, no attention being paid to grouping, as the coils are all alike.

On a large machine, the careful wedging of the coils in the slots is especially necessary, as the mechanical stresses that are brought to bear on account of the heavy currents in case of short-circuit, are very large. Hence the coil must fit very tightly in its place. If necessary, strips of treated cement paper, fullerboard or wood are

placed in the sides and bottoms of the slots to ensure a tight fit.

The first half of each coil is driven tightly into the bottom of the slot with a fiber drift and mallet. The coil which goes over it is also driven snugly into place. The fish paper cell is then cut off even with the top of the slot and folded over the coil. In order that this cell may not be torn by the wedge, a strip of treated fullerboard, the full width of the coil, may be laid into the slot, so that the wedge may slide over it readily, and at the same time compress the coil tightly into the slots. The wedges are, for convenience, divided into sections six to eight inches long and are driven into position by means of a standard wedge driver or a blunt chisel. If the wedge is a very tight fit, the coil is driven down with a drift just ahead of the wedge.

The four coil per slot diamond winding used with partly closed slot cores, is assembled the same as any other diamond winding, with the exception that two coils lie side by side in both the bottom and top of the slot. The shape of the slot is such that no difficulty is encountered in inserting the second coil. This is essentially an induction motor winding, being used quite generally on both stator and rotor of large machines.

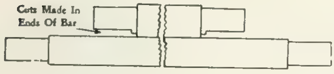

FIG. 110—ENDS OF UPPER AND LOWER BARS—BAR AND END CONNECTOR WINDING

Double Windings—On large induction motors, two speeds are sometimes secured by the use of two separate windings in the same slots, connected for a different number of poles. In this case the windings are so designed that the coils for one speed lie inside the coils for the second speed. The two windings are assembled at the same time, each pair of coils being treated as if it were a single coil of a one speed winding. Each slot thus contains four coils one above the other. In such cases it is quite common to have the two windings of widely different capacities, depending, of course, on the load to be carried at the separate speeds.

TESTING

After the coils on any of the types of winding described are all in place, their free terminals are temporarily connected together, and they are tested for break down to ground, with the standard voltage for the size and type of machine. After the coils have been connected into groups, and the groups connected into phases they are tested for break down between phases, and for short-circuits between turns.

The break down test consists of the application of the standard break down voltage from the conductor to ground and from phase to phase. The test for short-circuit consists in placing an alternating-current magnet of the type shown in Fig. 105 over one side of the coil or group, and holding a light piece of steel over the other side of the coil. If current flows in the coil, the piece of steel will be attracted. As no current can flow under normal conditions, this test is a sure indication of short-circuits. It cannot be applied where the groups are connected in parallel but must be made, in this case, before they are connected. No further tests are usually made until the machine is assembled.

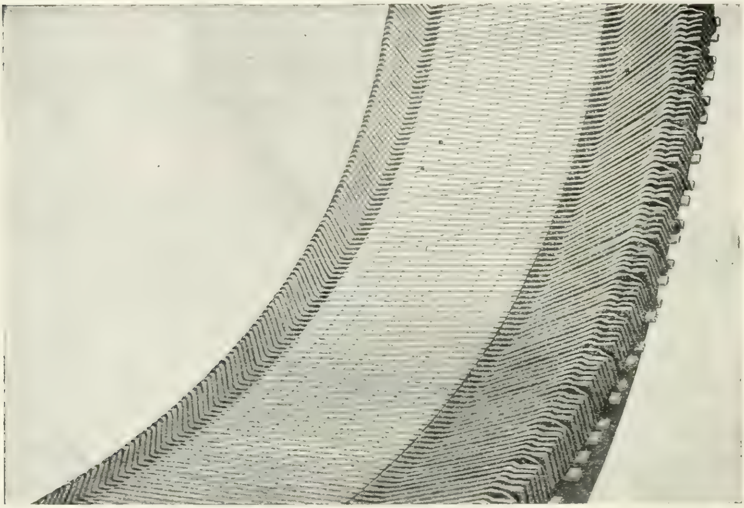

FIG. 111—PART OF DIAMOND WINDING OF 3 200 HORSE-POWER INDUCTION MOTOR

CONNECTING

The number of groups in any machine may be either one or two per phase per pair of poles, depending on the arrangement of the coils and groups. The coils of each group are connected in series. The groups in a phase may be connected in series, parallel or series-parallel, although for voltages of 2 200 or higher, they are nearly always connected in series The phases on a two-phase machine are never connected together inside the machine. Three-phase machines are normally connected in star, though in special cases, terminals are brought out from induction motors so

that they may be connected in delta or star at will, to give a change in voltage.

On a concentric winding the groups are readily distinguishable. In a diamond or involute winding, the number of coils per group must be counted off, and the groups are temporarily connected by bending together the leads from a wire coil or by slipping a copper connector over the stubs from a strap coil. They are permanently connected by soldering the joints so made. Fig. 111 shows a diamond winding connected into groups. In this particular winding, the coils at the end of each group have special leads to facilitate connecting the groups into phases. On most machines, the connectors between groups consist of insulated copper strap, with suitable openings at each end to slip over the group leads. All joints are carefully soldered, and are smoothed up with emery cloth, so that no sharp pointed edges are left to damage the insulation.

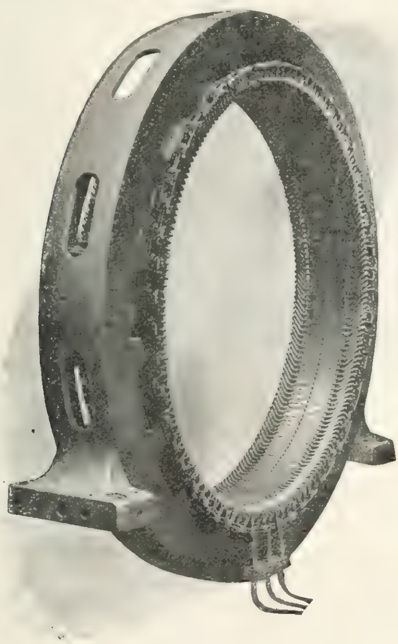

FIG. 112—200 KW GENERATOR SHOWING END CONNECTIONS

The connectors between coils, ordinarily called stubs, are insulated with treated cloth tape, with a protective covering of untreated cotton tape. Large stubs are sometimes covered with drilling caps, sewed to shape, and painted with insulating varnish after they have been fastened in place. Treated tape is wound over the joints in the insulation. The thickness of the taping and other insulation, depends on the voltage of the machine. The connectors between groups are ordinarily insulated and impregnated before they are put on the machine. The joints between the connectors and the group leads are insulated in the same way as the stubs. The form of connection ordinarily used with a lap diamond winding with groups connected in series is shown in Fig. 112.

Where double windings are used they are arranged for the connections to be made on opposite sides of the machine. Each winding is connected as if it were entirely independent.

BRACING

The stresses occuring in the end connections of a large machine, due to magnetic reactions between current carrying conductors, are quite large. In addition, these effects are greatly magnified in case of short-circuit on a generator. Some method of bracing these end connections is therefore necessary. This ordinarily takes

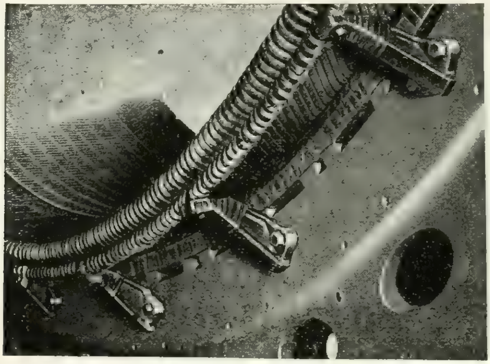

FIG. 113—VIEW SHOWING BRACING FOR DIAMOND COIL ENDS

the form of an insulated steel ring, to which the coils are tied with heavy twine. On a concentric winding a separate ring is used for each bank of end connections. On a diamond winding one ring at each end is sufficient. On a large machine, however, it is usually necessary to brace this ring by additional steel supports bolted to the frame, as shown in Fig. 113.

HISTORICAL EXHIBIT OF LAMPS

IN the large exhibition room of the Rochester Railway & Light Company, Rochester, N. Y., is an interesting collection of various illuminants. This collection was prepared for use as a special exhibit elsewhere, but now forms an interesting feature of the public exhibition and demonstration room of the Company. The collection is not complete but it serves to bring out the important stages in the development of indoor lighting.

The several exhibits are accompanied by explanatory legends which are as follows:—

"*Pine Torch*—Earliest known form of artificial illumination."

"*Betty Lamp*—Used by ancients and American colonists up to 18th century, burning animal and vegetable oils."

"*Fluid Lamp*—Used during middle of 19th century burning camphene, an explosive mixture of alcohol and turpentine."

"*Candle*—Used from about 1740 up to present.
Cost—25/100 cents per candle-hour."

"*Open Flame Gas*—Used from 1817 to present.
Cost—3/100 cents per candle-hour."

"*Rochester Burner*—Used from 1860 to present, burning kerosene oil.
Cost—2/100 cents per candle-hour."

"*Carbon Incandescent Lamp*—Used from 1880 to present.
Cost—6/100 cents per candle-hour."

"*Reflexolier*—Used from 1900 to present.
Cost—7/1000 cents per candle-hour."

"*Mazda Lamp*—Used from 1909 to present.
Cost—12/1000 cents per candle-hour."

A 200 000 VOLT ELECTROSTATIC VOLTMETER

A. W. COPLEY

THE condenser type terminal which was described in the October issue of the JOURNAL* has rendered possible the construction of an electrostatic voltmeter for a range of 10,000 to 200,000 volts and a high degree of accuracy throughout. An exterior view of the meter is shown in Fig. 1. A detail view of such an instrument was given in this article as an illustration of the application of the condenser principle.

FIG. 1 — ELECTROSTATIC VOLTMETER

An electromagnetic voltmeter for high potentials consists of a low potential voltmeter element with resistance connected in series. The form of voltmeter here described consists of an electrostatic voltmeter element which in effect is connected in series with one or more condensers for high voltage measurements and directly across the circuit for lower voltage measurements. By the combination of the electrostatic voltmeter and the condenser terminal accurate high voltage measurements can be effected which were hitherto impossible or at best very inconvenient.

Th meter element consists of two stationary curved aluminum plates, between which is suspended a movable vane, with a light coiled spring so adjusted that the pointer remains at zero with no voltage on the meter and gives the full scale deflection at the proper voltage. The complete moving element and its mounting are shown in Fig. 2. When a difference of potential exists between the stationary vanes, the moving vane, which is in the position shown in Fig. 3, rotates in the direction of the arrow, in its attempt to shorten the distance between itself and the stationary plates. The meter is placed in a sheet iron tank filled with transformer oil. This is necessary from the insulation standpoint as the distance between live parts is less than the break down distance in air. At the same time it makes the meter practically dead beat, the oil acting as a damper.

The scheme of connections is shown in the diagram, Fig. 3. The electrostatic voltmeter element is shunted across one or more

*Article by Mr. A. B. Reynders, Oct., 1910, p. 766.

metal layers of the condenser terminal of the instrument. Thus the voltage impressed is but a fraction of the total voltage from line to ground. Metal rings or collars are connected to two of the metal layers, dividing the series of condensers from line to ground into three sections. The first section marked *a* in Fig. 3 and shown for simplicity as two condensers in series has a potential of one-half the line voltage impressed across it, while sections *b* and *c* have each a potential equal to one-quarter of the line voltage impressed upon them. The voltmeter element *d*, which is shunted across section *c*, is thus seen to operate on a voltage of one-quarter the impressed voltage, or 50 000 volts when 200 000 volts is impressed across the terminals. For the measurement of voltages not exceeding 100 000 volts, section *a* is short-circuited. Sections *b* and *c* then have one-half the line voltage impressed upon them, so that the meter element still has 50 000 volts across it when the full rated voltage is impressed on the terminals. In a similar manner, for measurement of voltages not exceeding 50 000 volts, sections *a* and *b* are both short-circuited, i. e., the meter element is connected directly across the line.

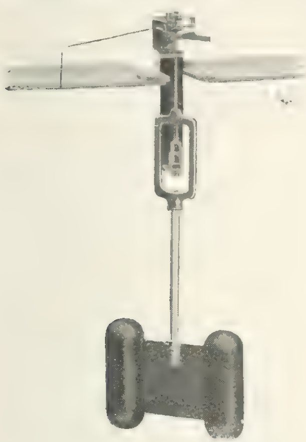

FIG. 2—MOVING ELEMENT OF ELECTROSTATIC VOLTMETER

The adjustments of the meter for the respective ranges of voltage are made by means of a string passing through the cover of the tank and running to the lower end of the condenser terminal where it is attached to a brass chain which runs up inside the terminal and is fastened to a long spring. When the string hangs free the condesers are all in series and the instrument is given a maximum voltage range of 200 000 volts. When the string is pulled up a short distance the chain comes in contact with the lower metal collar. Approximately one-half of the series of condensers of the terminal corresponding to section *a*, Fig. 2, are thus short-circuited through the chain. By pulling the chain up

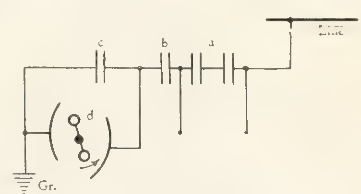

FIG. 3—SCHEME OF CONNECTIONS

into contact with the second or upper collar the section of the condenser corresponding to *a* plus *b* of Fig. 3 is short-circuited.

As there is no ready means of changing and adjusting the amount of the capacity in the various sections of the terminal, the meter reading for a given outfit cannot be adjusted on lower ranges to give exactly 100 000 and 50 000 volts, respectively, at full scale reading. Two scales are therefore used; a lower scale indicating directly in kilovolts on the highest range and an upper scale divided into even divisions. This latter scale is used in connection with calibration curves for the lower ranges. A typical curve is shown in Fig. 4. In this instance the 100 000 volt range comes exactly correct, but the 50 000 range gives 46 000 volts for full scale. By reference to the curve it may readily be seen that the meter will give fairly accurate readings for voltages as low as 100 000 volts, which gives a deflection of ten percent of the length of the scale when the 50 000 volt range is used. The ranges overlap sufficiently to give readings of high accuracy for all potentials between the minimum and 200 000 volts.

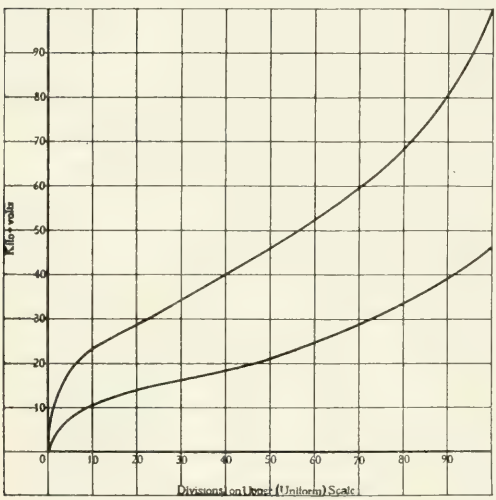

FIG. 4—CALIBRATION CURVES OF LOWER RANGES OF ELECTROSTATIC VOLTMETER

Upper curve is for 100 000 volt range and lower curve for 50 000 volt range.

Transmission line potentials of 50 000 volts and higher are no longer unusual and the insulators and station equipment for these lines must be tested at voltages considerably above normal. This meter affords a simple and reliable means for measuring the high test voltages on such lines. Its importance in the investigation of special conditions found with circuits of extremely high potential is readily recognized. As a laboratory instrument it finds wide application because of its accuracy, reliability and the large range of voltages covered by a single meter.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

507—Effect of Special Method of Connection of Induction Motor to Two-Phase Generator—If a two-phase induction motor is connected to a two-phase generator as shown in Fig. 507 (a), so that the respective phases of both machines are all in series what will be the effect on the operation of the motor? T. G. W.

Whether the two generator windings corresponding to the two phases are inter-connected or separate the effect of such a connection would be to impress a single-phase voltage on the motor. The motor would in turn have the operating characteristics of a single-phase motor, i. e., there would be no starting torque developed, but it would run equally well in either direction after having been brought up to speed. Unless a

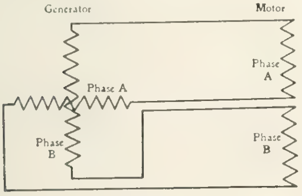

Fig. 507 (a)

suitable means of starting were provided the arrangement of connections would be in effect a short-circuit on the generator. Whether the generator phases were inter-connected or not the voltage impressed on the motor windings would be in effect the same as normal, with the connections between the motor and generator made as shown in the diagram. If the generator phases were not inter-connected the effective voltage delivered by the generator would be equivalent to 1.41 times the voltage normally delivered by one phase when the machine is operated as a two-phase generator. If the phases were inter-connected the effective voltage delivered would be one-half of this value. The connections of the motor, however, correspond to half voltage, and its operation would be the same as in the preceding case. The generator and motor would each be working at greatly reduced capacity on account of the single-phase characteristics, as explained in article by Mr. G. H. Garcelon on "Polyphase Motors on Single-Phase Circuits," in the JOURNAL for August, '05, p. 501. See also "Some Phenomena of Single-Phase Magnetic Fields," by Mr. B. G. Lamme, Sept., '06, p. 492. M. W. B.

508—Variation in Angular Velocity of Engine Shaft—What is the method of measuring the variation in the angular velocity of an engine shaft where the load is not electrical? Where may a complete description of the apparatus used be secured?

H. B. W.

Very close determination of angular variation can be obtained in the following manner: A strip of paper is placed upon the periphery of the flywheel. A motor is provided, driven by current from a storage battery to insure constant speed. This motor is equipped with a small fly-wheel on which a marker is placed, and the apparatus is set close to the engine fly-wheel which carries the paper

strip so as to cause the marker to make lines on the paper corresponding to the consecutive revolutions of the marker. If the engine is revolving at constant angular velocity the marks will be at a uniform distance apart throughout the circumference of the flywheel. Variations in angular velocity will be indicated by differences in the distances between the marks, from which the angular velocity can be computed. This method of determining angular variation in speed of rotation was illustrated in an article by Mr. J. R. Bibbins in the Journal for February, 1909, pp. 101-104, the apparatus referred to being simply an elaboration of the above principle. E. D. D.

509—Method of Cross-Connecting Primary Windings in Induction Motor—In the case of a 60 hp, three-phase, 2200 volt motor, speed 700 r.p.m, ten poles, total number of coils 120, the coils are so connected that five poles are joined by long jumpers in series in a counter-clockwise direction, after which a short jumper is run clockwise to connect the remaining five poles of the same phase. Why is this? How can these coils be grouped for two-phase? G. K. M.

The two principal reasons for using the method of connection mentioned may be outlined as follows: First, it gives a convenient means of connecting from full to half voltage without running the additional extension of lead and star connection half way around the motor. This means a considerable saving in space required for connections since the group connectors are preferably smaller than the star and lead connectors. There is probably an additional saving in space in that there are no cross-overs of connectors in each half circuit which is met with if the same circuit takes in north and south poles successively. Second, by distributing the poles around the circumference of the machine alternately any eccentricity of the rotor in respect to the stator is made to affect the circuits equally and thus, when the parallel connection is used for half voltage, the internal currents of the winding will balance, thereby tending to make the windings operate at a uniform temperature. The motor may be re-connected for two-phase by dividing the 120 coils into 20 groups of six coils per group, reconnecting in a manner similar to the three-phase connection, but forming only two phases; both ends of each phase are brought out for leads. It should be noted, however, that the motor, reconnected for two-phase without changing the winding in the slots, should be operated on about 1700 volts instead of 2200 volts to obtain satisfactory operation. For further information see pp. 13-14 of the Six-Year Topical Index of the Journal. M. W. B.

510—Series Motors in Series—Some time ago a salesman made the statement that if two series motors were running in series with each other, as is the case in mine locomotives, and one of them became locked so that its armature could not rotate, there would cease to be a torque on that motor, and that the other motor would then nearly make up in power for both motors. If this is true, or any phase of it is true, please explain the phenomenon. Why, if current is flowing through both armature and field, is there no torque? He explained it on the ground that the locked motor is at very nearly ground potential, due to the slight resistance of armature and field. But, that granted, why is there not a torque? G. L. A.

If two duplicate series motors are running in series, theoretically the one will exert the same torque at the shaft as the other, no matter what the condition of load, even if one or both are locked, since the torque of each depends only on the amount of current flowing, and since, being in series, the current of one is at all times the same as in the other. If, for any reason, one armature becomes locked it can generate no counter e.m.f. and the second motor

on full line voltage, diminished only by the *ir* drop in the armature, series field and brushes of the first motor. F. A. R.

511—Series Direct-Current Versus Wound Secondary Induction Motors for Crane Service—What objections are there to using three-phase induction motors on high speed cranes for foundry and machine shop work? By having wound rotors with slip rings and a suitable controller, why should they not give just as good satisfaction as direct-current motors? I have seen them used on slow speed cranes but not high speed. W. J. P.

There are no objections to using three-phase induction motors on high-speed cranes for foundry and machine shop work and such motors are being employed. The maximum speed that has been used is 1120 r.p.m. A higher speed than this would not be admissible owing to too high speed of gearing. Generally ten or 12-pole motors are used on cranes on 60 cycle circuits, giving a motor speed of 690 or 580 r.p.m., and four or six-pole motors on 25 cycles, giving a speed of 720 or 480 r.p.m. In general, the wound rotor, slip ring induction motor gives just as good satisfaction on cranes as direct-current motors. However, the characteristics of the slip-ring induction motor are not quite as good as the direct-current motor for high-speed service, but the slip-ring induction motor approaches these characteristics nearer than any other type of alternating-current motor. A wound secondary induction motor has to have a synchronous speed corresponding to the highest speed at which it is required to operate and lower speeds are obtained by the introduction of external resistance in the secondary circuit at a certain sacrifice of efficiency, while the series direct-current motor gives change of speed automatically with variation of load. The alternating-current motor gives the same speed when raising the hook as when lowering it, while with the direct-current motor when there is no load on the hook, it can be run much faster going down, an advantage possessed by direct-current motors over alternating-current for crane service. For alternating-current motors above 15 hp, we would not recommend using motors of higher speed than 850 r.p.m and below 15 hp, 1120 r.p.m. For performance characteristics of wound rotor type induction motors with external secondary resistance see article by Mr. A. M. Dudley in the JOURNAL for July, 1908.

W. H. P. & B. G. L.

512—Mechanical Design Details—Please give method of calculating the following: *a*—What kind of band wire is best on a direct-current armature, and the maximum stress allowable? *b*—For finding the stress in commutator necks, do you consider the whole weight of the neck in this calculation? What is the maximum stress allowable? *c*—For finding the size of bolts required for holding on the poles and coils, on a large alternating-current revolving field alternator and the maximum stress allowable in the bolts? *d*—For finding the size and length of bearings required, what do you take into consideration, and is the same formula used for all types of alternating-current and direct-current machines? P. A.

a—For banding wires, use tinned steel wire of an ultimate strength of about 170 000 lbs. per sq. inch. Work between 35 000 and 40 000 per sq. inch at normal speed. *b*—If the neck is unsupported consider the entire weight of the neck. The permissible stress in copper is from 5 000 to 8 000 lbs. per sq. inch. *c*—The maximum allowable stress at the root of the threads is 5 000 lbs. per sq. inch for normal speeds, and 7 000 to 8 000 lbs. per sq. inch for over speeds. *d*—Maintain a proportion of length to diameter of about 2.5 to 1, and a pressure of about 60 lbs. per sq. inch viz., surface equals diameter ti and the wire of

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only the outgoing

513—Reversing Two-Phase Motor—Can a two-phase motor be reversed by reversing one phase of motor when connected to a two-phase, three wire system? Please explain graphically what will happen if the motor does not reverse? J. H.

A two-phase motor which is operating on a two-phase, three wire circuit may be reversed by reversing one phase of the motor. That is, given the line wires L', N, L'', and the motor leads A_1—A_2; B_1—B_2, with connections L' to A_1; L'' to B_1; and N to the common lead A_2, B_2; to reverse the direction of rotation connect L' to A_1; L'' to B_2; and N to the common lead A_2-B_1, as shown in Fig 513 (a); or L' to A_2, L'' to B_1 and N

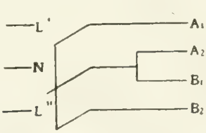

Fig. 513 (a)

to the common lead A_1, B_2; The motor may also be reversed by reversing two of the three terminals, the neutral connections remaining unchanged. Thus, given the original connections, to reverse the motor connect L' to B, L'' to A_1, with connection N to A_2 B_2 unchanged. For further information regarding the action of two-phase induction motor see Nos. 73, 159, 292, and 214, including references therein. M. W. B.

514—Induction Motor Changed to Synchronous Motor—What changes would be necessary in the stator windings of a five hp. 550 volt, 60 cycle, six-pole, three-phase induction motor, speed 1130 r.p.m., in order to operate it as a synchronous motor by replacing the rotor with a synchronous motor type of field with the same number [illegible] excited by direct-curr[illegible] stator windings are Y-[illegible] Would it be [illegible]ecessar[illegible] [illegible] the stator is [illegible] get a different number of stator poles? Would the efficiency and other performance of such a motor be satisfactory for reconnecting as above? W. J. P.

If the speed is to be approximately the same as that for operation as an induction motor the new rotor should have six poles. The synchronous speed will then be 1200 r.p.m., no change in the primary windings being required. The operation should prove satisfactory, provided the synchronous rotor has suitable proportions. Its field strength must be greater than its armature strength in order to have proper synchronizing power. As the magnetizing ampere turns on the induction motor are usually about one-third the stator full-load ampere turns, while on the synchronous motor the magnetizing ampere turns should be equal to or greater than the stator full-load ampere turns, it is evident that the air gap of the synchronous machine must be much larger than that of the induction motor, the same stator winding being used. Hence, proper proportions must be chosen to give this suitable field strength.

S. N. C. & B. G. L.

515—Balanced Three-Wire, Single-Phase Load on Three-Phase Distribution Circuit—It is desired to supply power to a set of three-wire, 220/110 volt, single-phase mains that may have a load of 160 kw, in such way as to maintain balanced load on the three phases of the primary distribution circuit. Is it possible to connect three single-phase transformers in such way as to give this condition and at the same time make it possible to measure the current on the secondary side with a single meter? The attached connections show a suggested arrangement. Would this give satisfactory results? W. C. M.

It is not possible by the use of [illegible]single-phase transformer or of a [illegible] single-phase transform[illegible] single-phase current [illegible]rcuit from a three-[illegible]of supply, so as to

maintain balanced load on the three phases of the primary distributing circuit. The connection submitted shows the primary sides

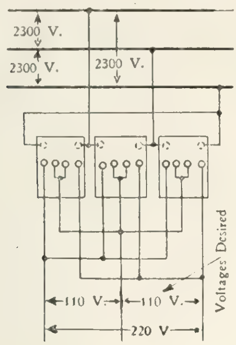

Fig. 515 (a)

of the three single-phase transformers connected in delta, and the three secondary sides connected in parallel. Since the voltages in the secondary windings of the three transformers maintain the three-phase relation, it would not be feasible to connect them in parallel, as there is an e.m.f. between them. The connection indicated would be equivalent to a short-circuit. E. G. R.

516—Size of Wire for Circuit Between Induction Motor and Switchboard—A 50 hp, 550 volt, 40 cycle, three-phase induction motor is located at a distance of 300 feet from the switchboard. The power-factor of the circuit is 85 percent. What size of wire will be required? Is the following statement, which appears in an article by Mr. Mershon on "Transmission Line Calculations," in the March, 1907, issue of the JOURNAL, applicable to this example: "Each conductor of a three-phase line must be of the same size required in a single-phase line transmitting half as much power, with the same percentage of loss at the same voltage." C. A. T.

The full-load current would be approximately 50 amperes per terminal. With this current the question of induction, and consequently of power-factor, need not be given consideration. Referring to any convenient wire table or formula it will be found that, for this length of circuit and current per line, allowing for a drop of 10 volts, a No. 5 copper wire would be of ample size. The statement quoted from Mr. Mershon's article applies in this case as well as in any three-phase, three-wire problem. C. H. S.

517—Abnormal Operation of Fire Alarm Circuit Paralleling Railway Feeders—One of our four fire alarm circuits gives a signal every time the east end circuit breaker goes out as a result of the cars bunching on that circuit. The line runs for a distance of 3150 ft. on the same poles as the four feeders, six inches below the latter, one of which causes the trouble. The alarm circuit consists of No. 10 B. & S., triple-braided wire, carrying a current of one-tenth ampere. The e.m.f. is 18 volts. The current is positive in the same direction as that of the railway circuit. At what current the breaker opens I cannot state, but it has been observed that the same action occurs when the machine breaker set at 900 amperes opens; it does not occur, however, when the breaker is purposely tripped. We have tried a two-microfarad condenser to ground but with no success. The alarm circuit is a series loop, free of grounds, and runs through a lead-covered cable made up of No. 14 rubber-covered conductor. The length of the cable is one and one-fourth miles, and the length of line paralleling the feeders is 3150 ft. on one street and the same on another street with another feeder. Total length of alarm [illegible] four miles. The arrang[illegible] News circuits is shown in Fig. 5[illegible]pany, R. [illegible]

The trouble is without doubt a result of the electro-magnetic induction between the wires carrying the power current and the wire of the alarm system. On account of the fact that only the outgoing

alarm wire parallels the feeder, its return being at a remote distance, there is a heavy magnetic field from the power wires cutting through the loop of the alarm circuit. As the current in the power wires gradually builds up, this field gradually increases and when the circuit breaker operates under the heavy load, the field is immediately reduced to zero; this causes a voltage to be induced in the fire alarm circuit which rings the bell. If the return wire of the fire alarm circuit ran close to the outgoing wire and was transposed with it along the distance where it runs

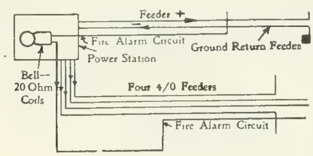

Fig. 517 (a)

on the same poles as the power wires there would be no trouble of this kind. However, as such an arragnement of the return wire is probably impracticable we would suggest that a condenser be connected in shunt across the alarm bell circuit, for the purpose of taking the discharge when the voltage is induced, or that the alarm circuit be carried as far from the feeders as the height of the pole will permit and still have the wire at the necessary height above ground. The magnitude of the inductive effect falls off rapidly as the distance between conductors is increased. A. W. C.

518—Series Transformers in Parallel on Secondary Side — If the primaries of two similar series transformers be connected in series and the secondaries in parallel, will the ratio of the transformers be exactly halved? The transformers are of 500 to five ampere capacity, i. e., having a ratio of 100:1. With the primaries in series and the secondaries in parallel, would the ratio be 50:1 and would the transformers follow the ratio curve at all loads? M. C. H.

The ratio will be 50 to one and if the same voltage is developed by each transformer, the ratio curve will be unchanged, i. e., if double the volt-ampere load is used at double the current. W. M. D.

519—Ground Return for Single-Phase High-Tension Circuit— For several years past a power company in California has been operating single-phase motors off a long transmission line, using one overhead conductor, and the earth as a return circuit. Transformers having one side of the high-tension winding connected to the single-overhead conductor, and one side grounded, step down the voltage to the operating range of the motors. We would be pleased to have you advise us the principle objections to such practice, and why, if practicable, such an arrangement is not used more extensively. The connections are shown in Fig. 519 (a). D. W. B. & J. H. K.

In general a single-phase ground return circuit has not been used except for railway systems for the reason that there are no suitable motors of large capacity

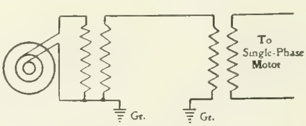

Fig. 519 (a)

and constant speed characteristics available for this work. The single-phase induction motors are built only in small sizes, and single-phase series motors of the commutator type are expensive, are not constant speed and are only suitable in general for railway service. Three-phase circuits ordinarily do not work well with one phase grounded, but may be operated with the neutral grounded or without any ground. Neither of the two latter conditions gives a ground return, however, for power current. Alternating-current circuits with ground return are objectionable on account of possible telephone and telegraph disturbances. R. P. J.

CONTRIBUTORS TO THE JOURNAL FOR 1910

Those who have also contributed to the JOURNAL previous to 1910 and for whom biographical sketches have therefore appeared in earlier December issues are indicated by a (*).

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B. F. FISHER, JR. (Penn. State College, '96), entered employ of General Electric Company in 1896, on general construction work and traveling under the direction of the Philadelphia office; in 1902, resigned to enter the employ of the United States Government as electrical engineer to the Quartermaster General; in 1908 resigned this position to enter the employ of the Westinghouse Lamp Company, as commercial engineer, which position he now holds.

N. E. FUNK (Lehigh Univ., '05) took apprenticeship course, Electric Company for one year; then connected with New York Central & Hudson River Railroad. During 1906-1907, instructor in electrical engineering, Georgia School of Technology; since then with the Philadelphia Electric Company, first as foreman of construction, and now assistant superintendent of operation.

H. G. GLASS, during the past twelve years connected with various operating companies, the main ones being the Monongahela Valley Electric properties, West Penn Railways Company, and the Washington Electric Company; more recently in charge of the electrical department, H. W. Johns-Manville Company, Pittsburg; now connected with industrial and power sales department, Electric Company.

DAVID HALL (Lehigh Univ., '96), 1896 to 1901 with the Card Motor & Dynamo Company, and the Bullock Electric Manufacturing Company as storekeeper, cost clerk, purchasing agent and designing engineer; 1901 to 1903, chief engineer, The Milwaukee Electric Company; 1903 to 1908, assistant chief electrical engineer, the Bullock Electric Manufacturing Company, and Allis-Chalmers Company; 1908 to date, designing engineer, power division, engineering department, Electric Company.

*STEPHEN Q. HAYES, general engineer on project work, engineering department, Electric Company.

RUDOLFH E. HELLMUND (Technical High School, Charlottenburg, Germany), after one year shop practice became assistant designing engineer for Mr. Julius Henbach; thereafter engineer in laboratory of cable factory; with Maschinenfabrik Esslingen on design of electrical apparatus; later in charge of test floor and power station; assistant to Mr. William Stanley, Great Barrington; designer in charge of motor design with Western Electric Company; at present engineering department Electric Company.

*E. M. HERR, first vice president, Electric Company.

*R. P. JACKSON, engineer on protective and mercury rectifier apparatus, detail and supply division, engineering department, Electric Company.

*C. W. JOHNSON, assistant manager of works, Electric Company.

*S. M. KINTNER, engineer, railway division, engineering department, Electric Company.

*H. L. KIRKER, engineer, railway construction department, Electric Company.

*J. H. KLINCK, industrial and power sales department, Electric Company.

M. B. LAMBERT, brakeman and telegraph operator, Long Island Railroad; dispatcher and later superintendent, Brooklyn Rapid Transit Company; for two years on apprentice course of Electric Company; for one year general foreman of electric equipment, Long Island Railroad; for two years assistant, first vice president's office and at present in charge of railway equipment division, railway and lighting department, Electric Company.

*P. M. LINCOLN, general engineer on power house and power transmission projects, engineering department, Electric Company.

A. W. LOMIS (Penn. State College, '07) entered apprenticeship department of the Electric Company immediately after graduation, remaining in this department one year, after which he took up work in the sales department; president of The Electric Club, 1909-10; now, Syracuse office, Electric Company.

H. E. LONGWELL (Cornell Univ., '83), draftsman with Dean Brothers Steam Pump Works, Indianapolis, for a year and one-half after graduation; entered the employ of Westinghouse, Church, Kerr & Company, January, 1885, and has been connected continuously with the Westinghouse interests in various capacities since that date; at present consulting engineer, Westinghouse Machine Co.

PAUL LUPKE, assistant general superintendent, Public Service Corporation, Trenton, New Jersey.

*T. D. LYNCH, engineer, research division, engineering department, Electric Company.

A. A. MILLER (Univ. of Nebraska, '98), draftsman, with the Electric Company for two years, from September, 1898; resigned to become assistant engineer of the Bemis Brothers Bag Company, assisting in the design of bag manufacturing machinery; entered the construction department of the Electric Company about one year later, and then the sales department, being appointed assistant engineer, New York Export office; 1902, salesman, Seattle office; at present, general supervision, railway and lighting work in this office.

*C. B. MILLS, mechanical engineer, industrial division, engineering department, Electric Company.

*H. N. MULLER, superintendent of distribution, Allegheny County Light Company, Pittsburg, Pa.

*L. A. OSBORNE, second vice president, Electric Company.

*JOHN C. PARKER, mechanical and electrical engineer, Rochester Railway & Light Company, Rochester, New York.

W. H. PATTERSON (Purdue Univ., '05), associated with Electric Company since 1905; at present connected with the industrial and power department.

*J. S. PECK, consulting electrical engineer, British Westinghouse Company.

R. A. PHILIP (Rose Polytechnic Inst.), electrical engineer, Stone & Webster Engineering Corporation, Boston, Mass.

*A. G. POPCKE, industrial and power sales department, Electric Company.

*K. C. RANDALL, engineer in charge, transformer and switchboard divisions, engineering department, Electric Company.

ALLEN E. RANSOM (Sheffield Scientific School—Yale Univ., '97), with Electric Company, 1897-1904, as follows: apprenticeship course; assistant engineer, erecting department of the Pittsburg office, and later of the Boston office; Seattle office two years; chief engineer, Lewiston-Clarkston Company, Lewiston, Idaho, 1904-1906, in charge of the design, installation and operation of a 60 mile, 45 000 volt, transmission system including two generating stations and seven sub-stations; 1906-1907, chief engineer, Fremont Power Company, Sumpter, Oregon; 1907, to date, Seattle office, Electric Company, in charge of industrial and power department.

*E. G. REED, designing engineer, transformer division, engineering department, Electric Company.

*CLARENCE RENSHAW, engineer, control section, railway division, engineering department, Electric Company.

A. B. REYNDERS (Univ. of Tennessee, '95), after four years of repair, installation and central station experience, entered the employ of the Electric Company, June, 1899, as draftsman; at present assistant to manager of engineering.

L. G. RILEY (Case School of Applied Science, '06) was on the engineering apprenticeship course of the Electric Company for one year, and with the railway construction department for one year; at present, railway division, engineering department on control apparatus design.

THOMAS W. ROLPH, in charge of the design division, engineering department, Holophane Company, Newark, Ohio.

YASUDIRO SAKAI (Univ. of California, '04), after graduation, took the Electric Company's engineering apprenticeship course, upon completion of which he accepted the position of assistant to Mr. Frank Conrad, general engineer of the detail and supply division, engineering department.

J. R. SANBORN (Mass. Inst. of Tech., '04) spent six years in engineering work with the Electric Company and in August, 1910, assumed the position of manager of works, Art Metal Construction Company, Jamestown, New York, which position he now holds.

F. W. SCHEIDENHELM (Cornell Univ.), after incidental engineering experience, was employed by West Penn Railways Company, first on transmission line work in 1905, and from 1906 to 1908, in charge of various structural design and construction, specializing particularly in reinforced concrete work; in 1908 he was appointed structural engineer of the above company; in the spring of 1909 he resigned to enter private consulting practice in which he is engaged on engineering reports and construction, special attention being given to hydro-electric work.

*CHAS. F. SCOTT, consulting engineer, Electric Company.

KARL A. SIMMON (Univ. of Minn., '05) completed the apprenticeship course, Electric Company, in 1907, since which time he has been connected with the railway division, engineering department.

*C. E. SKINNER, engineer in charge, research division, engineering department, Electric Company.

*R. A. SMART, formerly assistant manager of works, Electric Company; now works manager, Oliver Chilled Plow Works, South Bend, Indiana.

*E. H. SNIFFIN, vice president and sales manager, Westinghouse Machine Company.

H. C. SOULE (Syracuse Univ., '03) took the apprenticeship course of the Electric Company, and after becoming associated with the transformer division of the engineering department, was appointed engineer in charge of the design of air blast transformers, railway transformers and auxiliary transforming apparatus for single-phase railway equipments.

G. I. STADEKER (Armour Inst. of Tech., '09), after graduation, was employed for several months as draftsman for the Green Fuel Economizer Company, after which he joined the apprenticeship course of the Electric Company; since September, 1910, he has been connected with the electric locomotive operating department of the Pennsylvania Railroad at New York City.

*C. E. STEPHENS, engineer, arc lamp section, detail and supply division, engineering department, Electric Company.

*W. R. STINEMETZ, engineer, erecting department, Electric Company.

*E. C. STONE, engineer, transformer division, engineering department, Electric Company.

*N. W. STORER, engineer in charge, railway division, engineering department, Electric Company.

*PERCY H. THOMAS, of Thomas & Neall, consulting engineers, New York and Boston.

W. A. THOMAS (Penn. State College, '98), testing department, General Electric Company, 1898-1899; engineer in foreign department, Central Electric Company, 1899-1902; electrical engineer, Pennsylvania Coal & Coke Company, Cresson, Pa., 1902-1904, since which time he has been connected with the industrial and power department of the Electric Company as commercial engineer in charge of mining, general hoisting and pumping work.

ALBERT WALTON (Cornell Univ., '02), erecting engineer, Archbold-Brady Company, 1902; superintendent, Citizens Light & Power Company, Auburn, New York, 1903; erecting engineer, Electric Company, New York office, 1904; commercial engineer, Electric Company, Boston office, 1905-1910.

E. C. WAYNE (New York Univ., '05), with Electric Company since graduation; apprenticeship course, one year; railway sales department, three years; industrial and power sales department, since 1909.

GEORGE WESTINGHOUSE, Pittsburg, Pa., president, American Society of Mechanical Engineers.

W. B. Wilkinson was for eighteen years superintendent of the Mount Vernon (Ohio) Railway & Light Company, during which time he was also for two years manager of the Wilkinson Electric Company, a local construction and contracting company; for the last four years, in charge of central station motor department, Pittsburg district office, Electric Company.

*Leonard Work, erecting department, Philadelphia office, Electric Company.

T. H. B. Whipple was for nine years in the woolen business with H. W. Reese, Louisville, afterwards was for twelve years with a body of Cleveland capitalists who controlled the Western Mineral Wool Company, The Buckeye Electric Company and The Jandus Electric Company as either branch manager or general agent of the three companies. For the past nine years he has held various positions with the Electric Company, but during about two years of this time acted as trainer for some three hundred salesmen of H. W. Johns-Manville Company, doing co-operative work in the incandescent lamp department for the Electric Company. At present Mr. Whipple is manager of the school for apprentices in the commercial training department of the Electric Company.

CONTRIBUTORS TO THE JOURNAL QUESTION BOX—1910

The diversity of the subjects touched upon in the inquiries received by The Journal Question Box is such that this department draws upon a very large variety of sources of information. Each answer is prepared by, or ultimately approved by, a specialist who is a recognized authority on the particular subject in question, and authentic information is thus assured. The majority of questions received demand answers borne of experience and good judgment. It is accordingly interesting to note the following list of those who have served in an advisory capacity in connection with the questions and answers published during the year. The majority of these men are associated with the engineering or commercial departments of the Electric Company at East Pittsburg.

J. L. Adams, Jr., detail and supply division, engineering department.

R. W. Atkinson, assistant to chief engineer, Standard Underground Cable Company.

J. Bache-Wiig, power division, engineering department.

M. W. Bartmess, industrial division, engineering department.

A. P. Bender, transformer division, engineering department.

D. A. Bowen, detail and supply division, engineering department.

William Bradshaw, detail and supply division, engineering department.

H. W. Brown, detail and supply division, engineering department.

D. E. Carpenter, industrial and power sales department.

W. N. Chaffee, transformer division, engineering department.

G. L. Christman, detail and supply division, engineering department.

L. W. Chubb, research division, engineering department.

S. N. Clarkson, general engineering department; now with Union Electric & Power Company, St. Louis, Mo.

J. E. Coleman, engineering department, General Electric Company, Schenectady, New York.

F. Conrad, general engineer, detail and supply division, engineering department.

A. W. Copley, detail and supply division, engineering department.

W. M. Dann, transformer division, engineering department.

W. A. Dick, power division, engineering department.

E. D. Dreyfus, technical writer, Westinghouse Machine Company.

A. M. Dudley, industrial division, engineering department.

Thos. A. Edison, Orange, New Jersey.

R. S. Feicht, engineeer-in-charge, industrial division, engineering department.

A. B. Field, power division, engineering department.

B. F. Fisher, Jr., commercial engineer, Westinghouse Lamp Company, Bloomfield, N. J.

H. W. Fisher, chief engineer, Standard Underground Cable Company, Pittsburg, Pa.

L. H. Flanders, engineer, The Electric Storage Battery Company, Philadelphia, Pa.

William Foot, power division, engineering department.

G. H. Garcelon, industrial division, engineering department.

W. S. Hadaway, Jr., general engineer, heating division, engineering department.

F. W. Harris, detail and supply division, engineering department.

D. Harvey, detail and supply division, engineering department.

L. F. Howard, electrical engineer, Union Switch & Signal Company, Swissvale, Pa.

R. P. Jackson, detail and supply division, engineering department.

H. D. James, assistant to manager of engineering.

J. S. Jenks, superintendent of power, West Penn Railways Company, Connellsville, Pa.

O. S. Jennings, detail and supply division, engineering department.

O. M. Jorstad, railway section, engineering department.

A. Kingsbury, general engineer, engineering department, and consulting engineer, Pittsburg, Pa.

B. G. Lamme, chief engineer.

A. C. Lanier, industrial division, engineering department.

C. A. Lauffer, M.D., medical director, relief department.

E. E. Lehr, industrial division, engineering department.

H. Lesley, engineer-in-charge, The Electric Storage Battery Company, Philadelphia, Pa.

P. M. Lincoln, general engineer, engineering department.

T. D. Lynch, research division, engineering department.

H. G. MacDonald, detail and supply division, engineering department.

P. MacGahan, detail and supply division, engineering department.

L. A. Magraw, detail and supply division, engineering department.

J. E. Mateer, industrial division, engineering department.

E. Mattman, mechanical engineer, power division, engineering department.

F. D. Newbury, power division, engineering department.

W. H. Patterson, industrial and power sales department.

Dr. J. C. Pole, chief electrician, Cooper-Hewitt Electric Company, New York City, N. Y.

K. C. Randall, engineer-in-charge, tranformer and switchboard divisions, engineering department.

E. G. Reed, transformer division, engineering department.

C. Renshaw, railway division, engineering department.

F. A. Rew, industrial division, engineering department.

B. P. Rowe, general engineering department.

J. R. Sanborn, research division, engineering department; now manager of works, Art Metal Construction Company, Jamestown, N. Y.

C. H. Sanderson, detail and supply division, engineering department.

H. M. Scheibe, detail and supply division, engineering department.

C. F. Scott, consulting engineer.

R. Siegfried, general engineer, industrial division, engineering department.

C. E. Skinner, engineer-in-charge, research division, engineering department.

R. A. Smart, works manager, Oliver Plow Works, South Bend, Ind.

H. C. Specht, industrial division, engineering department.

E. C. Stone, transformer division, engineering department.

A. J. Sweet, engineer, Holophane, Company, Newark, Ohio.

H. B. Taylor, detail and supply division, engineering department.

A. A. Tirrill, president, Tirrill Manufacturing Company, Athens, Pa.

E. B. Tuttle, electrical engineer, C. D. & P. Tel. Company, Pittsburg.

Theodore Varney, industrial division, engineering department.

W. L. Waters, power division, engineering department.

J. E. Webster, railway division, engineering department.

T. Whitehead, industrial division, engineering department.

B. Wiley, industrial and power sales department.

L. Work, erecting department, Philadelphia, Pa.